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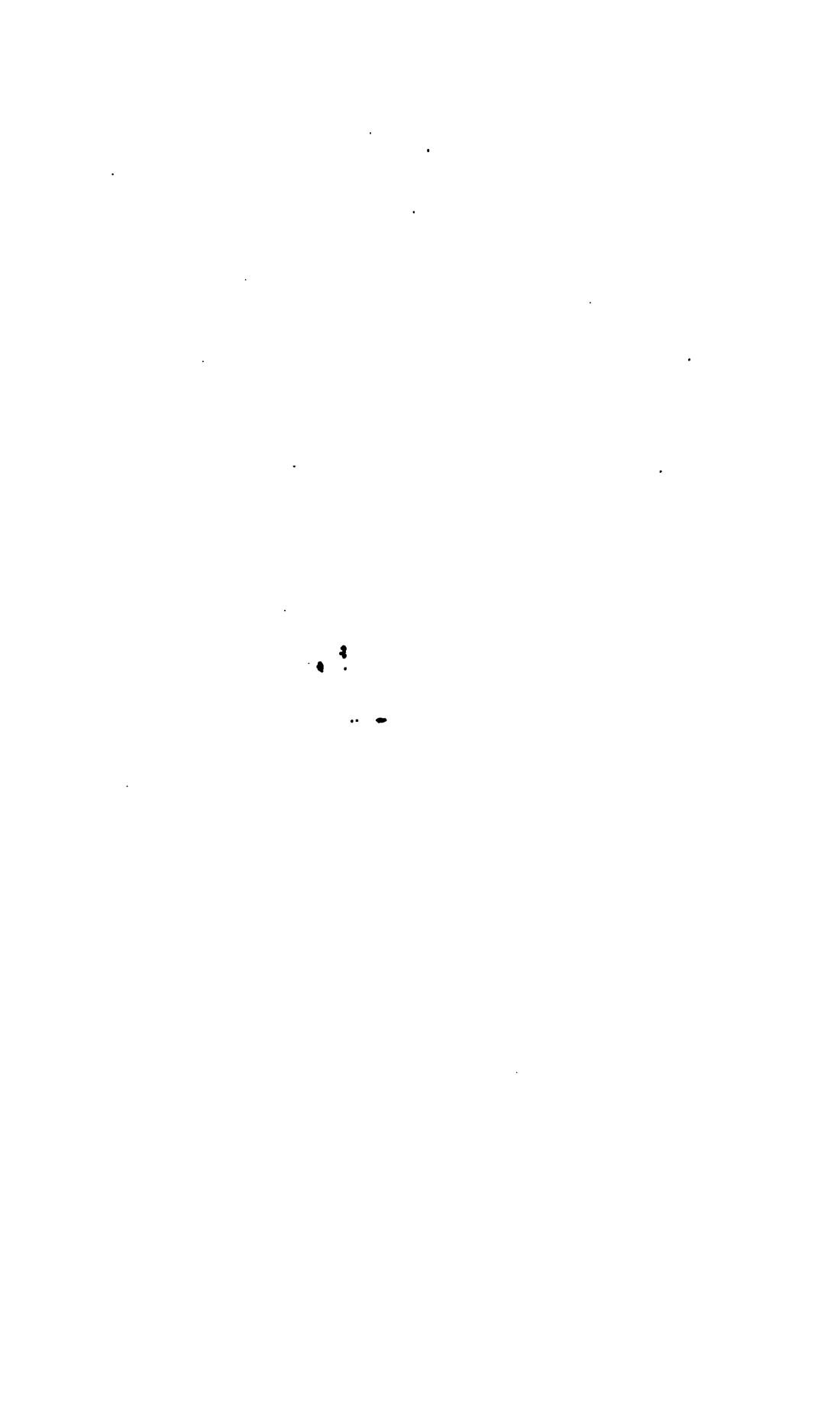
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Dormus & Harris

ANIMAL CHEMISTRY

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WITH REFERENCE TO THE

N.Y.

PHYSIOLOGY AND PATHOLOGY OF MAN.

J. N. SIMON.

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS, & MEMBER OF THE INSTITUTE OF PHYSIOLOGICAL CHEMISTRY,

TRANSLATED AND EDITED BY
GEORGE MURRAY, M.A. & L.M., F.R.C.P.

MEMBER OF THE ROYAL COLLEGE OF PHYSICIANS



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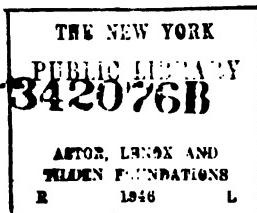
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EDITOR'S PREFACE.

I HAVE much pleasure in presenting to the members of the Sydenham Society a translation of Simon's 'Chemistry of Man,'¹ a work that obtained for its author a European reputation, and is universally regarded as by far the most complete treatise that has yet appeared on Physiological Chemistry. Until I became acquainted with this work in 1843, I entertained the idea of publishing a text-book of medical chemistry with the view of attempting to supply a deficiency in the medical literature of this country, which, I doubt not, has been felt by many of my brethren as much as by myself. But a careful perusal of the "Chemistry of Man" convinced me that I should be doing better service to the profession by undertaking a translation of that work than by the publication of a separate treatise. Impressed with this feeling I wrote to the author, who immediately offered me all the assistance in his power, and promised me a considerable amount of original matter. I regret to say that his early and unexpected death in the autumn of the same year rendered this promise of comparatively little value. I have, however, freely availed myself of the permission granted me by the Council of the Sydenham Society to insert such additions as the progress of chemistry, since the original publication of the work, has rendered necessary. These interpolations, with the exception of one class, are distinguished by being included in brackets. I refer to the chemical essays of Simon, written with the view of filling up occasional deficiencies in his 'Chemistry of Man,' and published in his 'Beiträge zur physiologischen und pathologischen Chemie und Naturgeschichte des Menschen,' excepting what was made

¹ Physiologische und Pathologische Anthropochemie mit Berücksichtigung der eigentlichen Zoochemie. Berlin, 1842.

at the request of Dr. Simon, and its expediency and fairness is unquestionable. The 'Chemistry of Man' was preceded by a volume entitled 'Chemistry of the Proximate Constituents of the Animal Body,' which, being in fact a distinct work, (containing upwards of 500 closely printed pages,) it has been deemed unadvisable to translate in its original form. A brief introduction,¹ in a great measure based upon it, has been drawn up by myself, with the view of facilitating the perusal of the work to those who have not paid much attention to the recent progress of organic chemistry; and having written it with this object, I have intentionally excluded many topics which some of my readers may consider should have found a place there.

The following sketch of the life and writings of the author, brief though it be, cannot be read without interest. It affords a striking illustration of the results that combined energy and talent are capable of evolving.

Franz Simon was the son of a surgeon residing at Frankfort on the Oder, and was born on the 25th of August, 1807. He distinguished himself at a very early age as a skilful apothecary; and, in volume 32 of 'Brande's Archiv.' we find his essay on the preparation and properties of tinctures, to which one of the Hagen-Buchholz prizes was awarded in 1829. Even in this essay we can trace the germs of some of his future speculations in physiological chemistry. The following year he obtained the first prize (the gold medal) for his essay on the best method of preparing infusions and decoctions (Brande's Archiv., vol. 35,) a treatise equally remarkable for the extreme accuracy and care with which his experiments were conducted, and for the judgment displayed in his conclusions. In the year 1832 Simon came from the Rhine, where he had been practising as apothecary in different towns (Cleve, Düsseldorf, Cöln, and Deutz,) to Berlin, where he passed his examination as apothecary with the highest credit, and where, in addition to the practical department of his pro-

¹ In the compilation of the Introduction I am likewise much indebted to Lehmann's 'Manual of Physiological Chemistry;' and to Mulder's 'Chemistry of Vegetable and Animal Physiology.'

fession, he attended lectures on chemistry and pharmacy. He now published a small pamphlet entitled 'A brief Examination of Professor Kranichfeld's Treatise on the Necessity of a Fundamental Knowledge of Pharmacy in relation to sound Medical Practice,' one of the most argumentative and powerful replies that Kranichfeld's absurd and unfounded accusation against the German apothecary system elicited. From this period till the year 1838 he devoted himself to study, having, with this view, given up his public pharmaceutical avocations in the year 1835. He attended, for six terms, lectures at the High School of Berlin, on natural history, physics, mathematics, history, and philosophy; he likewise published, conjointly with Dr. Meklenburg, a tabular view of chemistry (Berlin, Hirschwald.) Most of his leisure time at this period was devoted to toxicology, a subject on which he and his friend Dr. Sobernheim published a treatise which is regarded throughout Germany as the standard work on every thing connected with poisons and poisoning. Some of the most important original investigations on which this work was based were originally published in Poggendorf's Annalen, vol. 40.

On the 3d of October, 1838, Simon received the degree of Doctor of Philosophy for his celebrated thesis 'De Lactis Muliebris ratione chemica et physiologica,' which, in the course of the same year, was published, with considerable additions, in the German language (Die Frauenmilch, u. s. w. Berlin, Förstner, 1838,) and fully established his reputation as one of the most successful investigators of the age in the departments of organic chemistry and microscopy. It was regarded by Berzelius and others of our first chemists as the most perfect work on the subject of which it treats.

In 1839 his tabular 'View of the Mineral Springs of Europe, arranged with especial regard to their chemical composition and their physical and chemical characters' (Die Heilquellen Europas, u. s. w., Berlin, Förstner,) made its appearance, a work of very considerable labour, in which he collected and systematically arranged no less than 1045 analyses of European mineral waters; and in 1841 we find him an extensive contributor to Dr. Nicolai's 'Manual of Medical Jurisprudence,' having, in fact, executed the whole of the chemical and

toxicological portion of the work. About this time the first part of the 'Chemistry of Man' appeared; it was not, however, completed till the summer of 1842, in consequence of Simon's determination to render the work as rich as possible in original analytical observations. With this view he was a constant attendant at Schönlein's clinical class, where his chemical services were highly valued, as manifested by the frequent reference made to them by that distinguished physician in his published Clinical Lectures. Scarcely had Simon concluded the 'Chemistry of Man' before he entertained the idea of editing a quarterly periodical devoted to his favourite pursuits, physiological and pathological chemistry. It appeared under the title of 'Beiträge zur physiologischen und pathologischen Chemie und Mikroskopie, in ihrer Anwendung auf die praktische Medizin.' He lived to edit only three numbers. The fourth (edited by his friend Dr. Minding) contained the melancholy tidings of his death, which took place at Vienna on the 23d of October, 1843, after an illness of only four weeks. Though no longer amongst us, the good that he did died not with him; his works, no less than his example, have stimulated others to follow in his track, and to build upon the solid basis that he has left them. Even the very periodical that he commenced so shortly before his death is still conducted (under a different title) by an able chemist, and is producing results worthy of its original founder.

I gladly avail myself of this opportunity of expressing my obligations to the Council of the Sydenham Society for the promptitude with which they accepted my suggestion respecting the expediency of publishing an English edition of this work, and for intrusting me with the editorship of it: to one of that body, Mr. Ancell, I am very deeply indebted for the kind and valuable assistance that he has afforded me in the preparation of this volume for the press. Amongst the many other friends to whom my acknowledgments are due, I must especially mention Dr. Allen Thomson, Dr. Percy, Dr. Wright, and Dr. Golding Bird.

G. E. D..

Southwick Street, Hyde Park.

AUTHOR'S PREFACE.

THE completion of the 'Chemistry of Man' has been unavoidably delayed beyond the time at which it was advertised to appear, in consequence of the large number of original analyses that I found it requisite to institute. As, however, these analyses materially increase the value of the work, I trust that my apparent procrastination will be readily forgiven. The present volumes comprise physiological and pathological chemistry. They treat of the physical and chemical relations of the fluid and solid portions of the human body in a state of health, and of the modifications they experience in different diseases. Moreover, in every instance, the chemical examination of the fluids and solids of the lower animals is appended to each chapter. The order in which the various matters treated in these volumes are discussed must be regarded rather as natural than physiological. After the circulating fluids, viz., the blood, lymph, and chyle, with which I commence,—I treat of the secreted and excreted fluids, as, for instance, those of the chylopoietic system, of the female breast, of the mucous membranes and skin, of the kidneys, &c.: next in order, I take the faeces and vomited matters. I then consider the various tissues that enter into the composition of the animal body, as, for instance, the bones, muscles, skin, and glands; and I conclude with a description of various solid and fluid morbid products, such as calculi, tubercular and carcinomatous matter, drop-sical effusions, &c.

I have made myself practically conversant with the most approved methods of analyzing the different fluids and solids described in this work; and, as far as my resources permitted, I have endeavoured to determine the various physical and chemical modifications they un-

dergo in the course of different diseases. My attention has been especially directed to the study of those fluids that are of the greatest importance to the practical physician. Within the space of a few years I have made about 170 quantitative analyses of various animal matters, of which the very large majority refer to human blood, milk, and urine, and on which I lay the foundation for the pathological chemistry of those fluids. In fact, without these analyses it would have been impossible to publish a work worthy of the name of 'The Chemistry of Man;' for the essays of Andral and Gavarret on the blood, and of Becquerel on the urine, did not appear until I had made considerable progress in my work. I have deemed it, in every case, my duty to incorporate the results of other chemists with my own, and if, in any instance, I have failed in acknowledging the sources from which my statements have been drawn, the fault is one of inadvertence, not of design. All purely physiological matter, not bearing directly on chemistry, has been omitted; but microscopic investigation, especially in those instances in which it strengthens the evidence of experimental chemistry, has been deemed legitimately deserving of a place in this treatise.

My views regarding the metamorphosis of the blood, and its relation to nutrition and animal heat, were first communicated, at Erlangen in the autumn of 1840, to the medical and chemical section of Associated Naturalists; and my subsequent researches into the chemical constitution of the blood and urine confirm my belief in their general accuracy. These views may be summed up in the following terms: The blood is subjected to a continuous metamorphosis, which may be regarded as the expression of its vitality. The nutrition of the peripheral system is effected by the liquor sanguinis, not by the blood-corpuscles. The liquor sanguinis affords nutriment to the cells and organs, which possess an inherent power of selecting proper material, or of forming it from non-homologous matter, at the same time secreting the products of decomposition. The principal nutritive matters in the liquor sanguinis are albumen, fibrin, and fat. The chief products of this metamorphosis are the extractive matters and lactic acid, which occur in the excretions, especially in the urine. Urea,

bilin, and carbonic acid are either not products of the metamorphosis of the blood during the act of nutrition in the peripheral system, or at most they are only in part formed by it. They must be regarded as products of the vital energy of the blood-corpuscles, which, doubtless, possess the same power of attracting nutriment, and of throwing off decomposed products, as other living cells. The proper nutriment of these corpuscles is oxygen, albumen, and probably also fat, which are furnished them by the liquor sanguinis. The most important products of their metamorphosis are carbonic acid, urea, fibrin, extractive matters, and very probably some of the constituents of the bile. The leading and most important object of this vital energy of the blood-corpuscles is the production of animal heat, without which every function of the organism, nay, even life itself, would be instantaneously annihilated. The production of animal heat is due to the combination of oxygen with the carbon of the globulin;¹ the principal products of this reaction are carbonic acid and urea, or uric acid, (which is excreted as a substitute for urea in most of those classes of animals in which elliptic blood-corpuscles occur.) The urea excreted may thus be regarded as a measure or equivalent of the animal heat developed.

The production of blood-corpuscles and the formation of blood are intimately connected with nutrition: when the food is too scanty and insufficient, the amount of blood, and especially of blood-corpuscles, is diminished; when the nutriment is proper and abundant, the reverse takes place. In the former case, therefore, the vital energy is depressed, the secretions and excretions are diminished, and the animal heat sinks; while in the latter case exactly the reverse is observed. In the normal state there is an equilibrium preserved between the production and consumption of blood-corpuscles. The food is prepared, and to a certain extent assimilated, before it enters the blood. The vital energy of the blood-corpuscles continues even during a perfect abstinence from food, and carbonic acid and urea continue to be formed,

¹ [Simon's views respecting the production of animal heat approximate closely to those expressed by our countryman, Mr. Ancell, in his 11th lecture on the blood. See *Lancet*, 1840, vol. I. p. 829, or Dr. Posner's German edition of the collected lectures, p. 200.]

although their amount gradually diminishes in a direct ratio with the diminution of the blood-corpuscles.

Moreover, the amount of carbonic acid and the formation of urea are lessened by a torpid, and increased by an excited circulation; and in proportion to the amount of corpuscles and to the rapidity of the circulation, so much the higher is the animal temperature. Thus in birds we observe a high temperature, and the reverse in the amphibia. In chlorotic, and also in very aged persons we find a low temperature, and a diminished excretion of urea, while in inflammatory diseases, and after prolonged corporeal exertion the temperature rises, and there is either a relative or an absolute increase of urea; in the former case, even in the absence of all nitrogenous food. The capillary and cutaneous systems tend to regulate an excessive rapidity of the circulation, and to prevent the animal heat from exceeding a certain limit.

If we only knew whether, and in what manner, the pulmonary exhalation is changed in various diseases, (especially in relation to the amount of carbonic acid contained in it,) whether the carbonic acid always increases relatively with the urea, or in certain cases with the uric acid, and if further, we possessed experiments illustrative of the effects of diseases, and of varied diet on the bile, we should then have a more solid basis than we now occupy, on which to found our chemical inquiries, while the acquisition to the science of medicine would be positive and incalculable. The questions here invoked must, however, unfortunately, at the present time, be regarded as unanswerable. We cannot doubt that the pulmonary exhalation does vary, under different circumstances, in the amount of carbonic acid; for instance, more carbonic acid is exhaled during prolonged corporeal exertion than when the body is in a state of repose; although, as far as I am aware, no experiments on this subject have yet been instituted.¹ We have, however, conclusive evidence that the amount of urea is increased under these circumstances.

On the other hand, in the researches of Trommer regarding the passage of sugar into the portal blood of horses, this substance could

¹ [The experiments of Scharling on this subject were made after the publication of the 'Chemistry of Man.' A brief notice of them is given in p. 113 of this volume.]

not be detected in the chyle nor in the arterial or venous blood, which renders it more than probable that the liver not only serves the purpose of modifying the composition of the blood, but likewise effects the object of altering or removing abnormal substances from it that have been absorbed by the mesenteric veins. Hence this organ appears, in a certain degree, to take a share in the process of digestion, an opinion supported by Berzelius. Future investigations respecting the functions of the liver may lead to very important results, and throw much light on many of the most obscure departments of physiology.

Although very little has yet been done in physiological and pathological chemistry, the rational physician, who ventures to cast aside the trammels of dogmatism and empiricism, cannot, for an instant, doubt that pathology, therapeutics, and diagnosis, are only safely based on chemistry, physiology, and morbid anatomy: he cannot entertain a doubt that the same chemistry with which he scans the changes in crude inorganic matter, will likewise enable him, if not at present, yet surely at some future period, to detect the variations in the composition of the animal fluids and solids, some of which are dependent on physiological, others on pathological causes, and will throw a new light on the normal functions of the organism, as well as on the various processes of disease.

After contemplating the dependence of vital manifestations on the unceasing metamorphosis of the animal body, and the secretions and excretions as its products; after glancing at the physical and chemical modifications that these secretions and excretions undergo in numerous pathological conditions, and observing how these changes affect the structure and chemical conditions of the different organs, we can no longer entertain a doubt that all morbid phenomena are accompanied by metamorphoses in the organism, different from those that occur in the normal condition. But it will require an immense number of analyses in order to ascertain and determine these modifications, to express them in definite terms, to connect them duly with functional disturbances in the organism, or with other symptomatic phenomena; and, finally, as far as possible, to endeavour to discover

their origin. In such researches the mere chemist can do little: in order to produce results really serviceable to science, physiology and pathology are as essential as chemistry itself, and no one can hope to advance this department of scientific inquiry who does not include, in his own person, the chemist, the physiologist, and the pathologist.

Every science is slowly and gradually developed. Physiological and pathological chemistry forms no exception to this rule: it is still a mere infant science, that has scarcely attained a self-dependent existence. The reader must therefore not require of this work more than the present state of the science will enable me to present him with. He will find in it chemical facts which the physiologist and pathologist may render of further service: the few scattered ideas concerning the metamorphosis of the blood, and the probable connexion between various diseases and certain modifications in the composition of the different animal fluids, may serve as connecting links for further investigations.

The materials for my analyses have been chiefly derived from the Charité (hospital) of this city, from some of the public cliniques, from private practice, and from the royal veterinary school. I gladly avail myself of this opportunity of publicly expressing my thanks to Drs. Schönlein, Wolff, and Romberg, as well as to Professors Gurlt and Hertwig, and the other professional friends who have favoured me with their advice and assistance. I must likewise express my obligation to Dr. v. Behr, who assisted me for a considerable time in my researches on the urine.

That this work may succeed in encouraging a taste for the department of science, whose cultivation and further development is, at the present time, imperatively demanded by the medical public, is the most sincere wish of

THE AUTHOR.

BERLIN, April, 1842.

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CHEMISTRY OF MAN.

INTRODUCTION.

THE proximate constituents of the animal body may be divided into two great classes, the *mineral* and the *organic*; each of which admits of several sub-divisions.

I. MINERAL CONSTITUENTS.

The *Mineral Constituents* may be advantageously classed in three groups, comprising, i, Those which are of service in the animal body, in consequence of their physical properties; ii, Those which effect important objects in the system by their chemical actions; and iii, Those which, being only incidentally present, may be eliminated without exerting any unfavourable effect on the economy.

CLASS I. CONSTITUENTS USEFUL BY THEIR PHYSICAL PROPERTIES.

1. *Water.* This substance is so universally diffused, and its uses are so obvious as to render any observations unnecessary.

2. *Phosphate of lime*, in the importance of its physical properties to the animal organism, undoubtedly ranks next to water. Phosphate of lime or, as it is often termed, bone-earth, consists of 8 eq. of lime and 3 eq. of phosphoric acid; its empirical formula therefore is $8\text{ Ca O} + 3\text{ PO}_4$, but there can be no doubt that it is a compound of two tribasic phosphates of lime, namely $2\text{ Ca O, HO, PO}_4 + 2(3\text{ Ca O, PO}_4)$. It consists of 51.55 parts of lime, and 48.45 of phosphoric acid. It occurs in bone, blood, milk, urine, faeces, &c.

3. *Carbonate of lime* forms the principal part of the skeleton in the invertebrata; it also occurs in greater or less proportion in the bones of the higher animals and man, in the urine of the graminivora, and in certain morbid concretions. It contains 56.29 parts of lime and 43.71 of carbonic acid.

4. *Phosphate of magnesia* is very frequently associated with

phosphate of lime. In a crystalline state its formula is $\text{HO}_2\text{MgO}_2\text{PO}_4 + 2\text{HO} + 12\text{HO}$. (Graham in Phil. Trans. 1837.) It occurs in bone, blood, milk, shell of eggs, urine of man and carnivora, intestinal concretions, faeces, &c. After the removal of the water of crystallization it consists of 36·67 parts of magnesia, and 63·33 of phosphoric acid.

Phosphate of magnesia and ammonia, or, as it is frequently termed *ammoniaco-magnesian phosphate*, is a perfectly distinct salt. Like the former, it is a tribasic salt, of which the 3 atoms of base are, 1 atom of oxide of ammonium, and two atoms of magnesia, with 12 atoms of water of crystallization, 10 of which may be expelled without any loss of ammonia. Its formula therefore is $\text{NH}_4\text{O}_2\text{MgO}_2\text{PO}_4 + 2\text{HO} + 10\text{HO}$. Crystals of this salt have been observed in the excrements in typhus and other diseases; it is also present in certain states of the urine, and is a frequent constituent of urinary calculi.

5. *Fluoride of calcium* occurs in the animal organism in very minute quantity. It is much more abundant in fossil than in recent bones.

CLASS II. CONSTITUENTS USEFUL BY THEIR CHEMICAL PROPERTIES.

1. *Hydrochloric acid* exists in the digestive fluid of man, of the mammalia generally, and of birds. It has been detected by Lehmann in morbid saliva.

2. *Hydrofluoric acid* has only been detected in the gastric secretion of birds.

3. *Chloride of sodium* exists in the blood, gastric juice, urine, bone, cartilage, &c.

4. *Carbonate of soda* is a very common ingredient in the ash of animal substances; in most cases it is derived from compounds of soda with organic acids, especially lactic acid. It is also found in the urine of the graminivora.

5. *Phosphate of soda* occurs in the blood, lymph, chyle, bile, milk, and urine. Its formula is $\text{HO}_2\text{NaO}_2\text{PO}_4 + 24\text{HO}$. On the addition of muriate of ammonia to a solution of this salt, we obtain the "sal microcosmicus" of the older chemists, which is found in considerable quantity in decomposed animal fluids; its formula is $\text{HO}_2\text{NH}_4\text{O}_2\text{NaO}_2\text{PO}_4 + 8\text{HO}$. The recent investigations of Enderlin tend to prove that the phosphate of soda that most commonly occurs in the animal fluids and tissues, contains 3 atoms of soda, and may be represented by the formula $3\text{NaO}_2\text{PO}_4$.

6. *Chloride of calcium* is found in the gastric juice and saliva.

7. *Chloride of iron* (apparently the proto-salt) occurs in the gastric juice.

8. *Iron* is found in considerable quantity in *haematin*, the principal colouring matter of the blood; also in lymph, chyle, black pigment of the eye, hair, &c. In what state it exists, whether as a

peroxide or protoxide, or either, is not known. It is also found in lesser proportion in bile, urine, sweat, milk, &c. In some of these fluids it is stated to exist as a phosphate.

CLASS III. INCIDENTAL CONSTITUENTS.

1. *Chloride of potassium* is found in almost all the animal fluids.

2. *Alkaline sulphates* occur in small quantity in most of the animal fluids, in the blood, milk, urine, and sweat. Mitscherlich could not detect any alkaline sulphates in the saliva, and Lehmann has recently shown that they do not *exist* in the bile, although they may be *produced* in the ash.

3. *Carbonate of magnesia* has been found in alvine concretions, urinary calculi, &c., in man and the mammalia. It occurs in considerable quantity in the urine of the graminivora, and is a constituent of the shell of the egg. Berzelius suggests the probability of magnesia being contained in bone, not as a phosphate but as a carbonate, and that the phosphate of magnesia is produced during analysis.

4. *Manganese* has been found in the hair; it has also been detected in human gall-stones, (in one instance there was found as much as 0·3%¹ of the protoxide of manganese,) and traces of it have been observed in the urinary calculi of the graminivora.

5. *Silica* has been found in small quantity in the enamel of the teeth, in bone, urine, urinary, intestinal, and biliary calculi, hair, and saliva. It is found in considerable quantity in the excrements, the amount varying with the nature of the food. In the sheep the excrements have been observed to contain as much as 6·0% of silica.

6. *Alumina*. Traces of this substance were detected by Vauquelin, in human bones; it has been found in considerable quantity in fossil teeth and horns. The circumstance of its being an occasional constituent of intestinal concretions coincides with Lehmann's experiments, in which he found that when alumina was introduced into the system, it was carried off by the fæces.

7. *Arsenic* was recently stated by Orfila to be a normal constituent of human bone. This opinion has, however, since been withdrawn, and there is little doubt that there was some fallacy in his experiments.

8. *Copper* is considered by Devergie, Lefortier, and Orfila, to be a normal constituent of all the soft parts, as well as of the blood of healthy persons. Devergie^a analyzed the viscera of five persons and found it in every instance. It has also been found in the sweat.

¹ The notation % represents per centage.

^a These observations have recently been confirmed by M. Barre, who succeeded in finding both copper and lead in the bodies of two persons to whom they could not have been given for poisons. It seems from the analyses of Signor Cattanei that neither of these metals exists in the bodies of new-born children or infants; and Rossignon has recently pointed out the sources from which the bodies of adults probably derive their copper. He has found this metal in gelatin, chocolate, bread, coffee, sugar, &c.

9. *Lead* has been found by these chemists in the same cases as copper.

10. *Ammoniacal salts*. In the blood, lymph, chyle, and milk, there are no appreciable ammoniacal salts. They have been observed in some cases in the sweat, and they occur in a small proportion in the urine.

II. ORGANIC CONSTITUENTS.

The *Organic Constituents* may be arranged in two principal groups, the former embracing the nitrogenous, the latter the non-nitrogenous matters. In the nitrogenous group we have protein, and its various modifications—gelatin, bilin, and the products of its metamorphosis—haematin, urea, uric acid, &c.: in the non-nitrogenous we place the animal sugars, fats, lactic and acetic acids, &c. &c.

CLASS I. NITROGENOUS CONSTITUENTS.

1. *Protein*.

Under this head we shall consider three very important compounds which are formed in the vegetable kingdom, and which are also found to constitute the greater part of the animal body. These are Albumen, Fibrin, and Casein. Two most important discoveries have recently been made regarding these substances. The first is the discovery made by Mulder that albumen, fibrin, and casein are nothing more than modifications of one compound to which he has given the name of *Protein*, (from *πρώτη*, I am first,) which may be regarded as the commencement and starting-point of all the tissues: the second is, that protein, in every respect identical with that which forms the basis of the three aforesaid animal principles, may be obtained from similar elements in the vegetable kingdom. When the newly-expressed juices of vegetables are allowed to stand, a separation takes place in a few minutes. A gelatinous precipitate commonly of a green tinge is deposited, and this, when acted on by liquids which remove the colouring matter, leaves a grayish white substance, which has been named *vegetable fibrin*. It separates from the vegetable juice in which it was originally dissolved exactly as fibrin does from blood.

When the clarified juice of nutritious vegetables, such as cauliflower, asparagus, mangel-wurzel, or turnips, is made to boil, a coagulum is formed which it is absolutely impossible to distinguish from the substance which separates as a coagulum, when the serum of blood, or the white of an egg, diluted with water, is heated to the boiling point. This is *vegetable albumen*.

Vegetable casein is chiefly found in the seeds of peas, beans, len-

tils, and similar leguminous seeds. Like vegetable albumen, it is soluble in water, but differs from it in this, that its solution is not coagulated by heat. When the solution is heated or evaporated, a skin forms on its surface, and the addition of an acid causes a coagulum just as in animal milk.

"The chemical analysis of these three substances has led to the very interesting result that they contain the same organic elements united in the same proportion by weight; and what is still more remarkable that they are identical in composition with the chief constituents of blood, animal fibrin and albumen.

They all three dissolve in concentrated muriatic acid, with the same deep purple colour, and even in their physical characters animal fibrin and albumen are in no respect different from vegetable fibrin and albumen. It is especially to be noticed, that by the phrase identity of composition we do not here imply mere similarity, but that, even in regard to the presence and relative amount of sulphur, phosphorus, and phosphate of lime, no difference can be observed."¹

When animal or vegetable albumen, fibrin, or casein is to be used for the extraction of protein in a state of purity, the following steps are to be taken. The selected substance is successively washed with water, alcohol, and ether, for the purpose of removing extractive matter, fat, and soluble salts. It is then treated with dilute hydrochloric acid, which extracts the phosphate of lime and any other insoluble salts that may happen to be present. We now dissolve it in a moderately strong solution of caustic potash, and keep the solution for some time at a temperature of 120°, whereby the sulphur and phosphorus that are present form phosphate of potash and sulphuret of potassium.

The protein is then to be thrown down from the solution, after filtration, by acetic acid, which must be added only in very slight excess, as otherwise the precipitate would be redissolved. It must then be collected on a filter and carefully washed till every trace of acetate of potash is removed.

In this state it occurs in the form of grayish white gelatinous flocks, which, when dried, become hard and yellow, and give an amber-coloured powder. It is insoluble in water, alcohol, and ether, and is devoid of odour and taste. It readily absorbs moisture, and swells up, but regains its original form upon being heated to 212°.

Mulder has analyzed protein from animal and vegetable albumen, from fibrin, and from cheese or casein; Scherer has analyzed it from animal albumen and fibrin, from the crystalline lens, from hair, and from horn; and Dumas from animal albumen and casein.

The formulæ which these chemists have assigned to it approximate closely to each other, although they are not absolutely identical. As Mulder's original formula has been confirmed by the re-

¹ Liebig's Animal Chemistry, translated by Gregory, p. 47.

cent investigations of Schröder and Von Laer, we shall adopt it as the correct symbol of the composition of this substance. According to this view the composition¹ of an atom of protein is represented by the formula $C_{24} H_{31} N_5 O_{12}$. Its atomic weight is 5529.5, oxygen being 100, and its symbol is Pr . It burns when exposed to the air, without leaving any ash. When boiled for a considerable time in water, with free exposure to the air, protein becomes slowly oxydized. We shall revert to this subject presently.

Protein combines both with acids and bases. It dissolves in all very dilute acids, and forms with them a kind of neutral compound, which is insoluble or nearly so when there is an excess of the acid present. Hence if sulphuric, hydrochloric, or nitric acid be added to a solution of protein in a dilute acid, the protein is precipitated in an insoluble state; if however the excess of acid is removed by careful washing, the precipitate becomes again dissolved. Acetic acid and the ordinary (tribasic) phosphoric acid constitute an exception to this rule, as they dissolve protein in all proportions. Protein may be precipitated from any of its acid solutions by ferrocyanide and ferricyanide of potassium, by tannin, by anhydrous alcohol, by various metallic salts, and by the alkalies.

The Metamorphoses of Protein. a. *Sulphuric acid and protein.* On the addition of concentrated sulphuric acid to protein or to any of its modifications (albumen, fibrin, or casein) a gradual swelling ensues, and the substance assumes a gelatinous appearance. On the addition of water it contracts, and it is found to be perfectly insoluble in that fluid. It must be collected on a filter and boiled in water as long as a solution of baryta indicates that any sulphuric acid is being given off: it must then be heated with alcohol, and dried at a temperature not exceeding 260°. This is *sulphoproteic acid*. It appears as a yellow mass, is not easily pulverized, and is insoluble in water, alcohol, and ether, but dissolves in potash and ammonia. The salts of silver, copper, lead, and iron yield precipitates with the alkaline solutions of this acid. Its formula is $C_{24} H_{31} N_5 O_{12} \cdot SO_3$.

On the cautious addition of dilute sulphuric acid to an acetic acid solution of protein, we obtain Mulder's *sulpho-bi-proteic acid*, which is then thrown down as a flocculent precipitate. After washing it, and drying it at a temperature not exceeding 260°, it assumes a white appearance, and may be easily pulverized. With the alkalies it forms solutions from which many of the metallic salts throw down insoluble compounds. Mulder considers that it is composed of two atoms of protein, two of water, and one of sulphuric acid; hence it may be expressed by the formula $C_{50} H_{62} N_{10} O_{24} + H_2 O_2 + SO_3$.

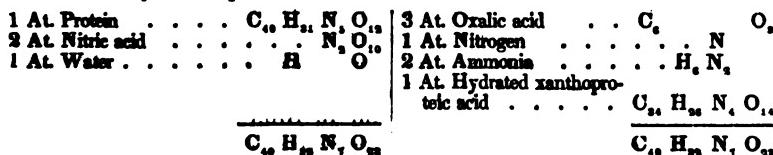
¹ Liebig's formula for protein is $C_{24} H_{31} N_5 O_{14}$. The numerical results afforded by these formulae approximate very closely. See Appendix I, Note 1.

If protein (or any of its modifications) be boiled in dilute sulphuric acid, a beautiful purple tint is evolved.

s. Hydrochloric acid and protein. Mulder has formed a *hydrochloro-proteic acid* in the same manner as the sulpho-proteic acid. Its formula is $C_{30}H_{52}N_{10}O_{10} + H_2O_3 + HCl$. When protein is boiled in strong hydrochloric acid the solution is at first yellow, but it gradually merges into a blue tint. This change of colour does not occur if the atmospheric air is excluded.

r. Nitric acid and protein. On the addition of nitric acid to protein or to any of its modifications, nitrogen and a little nitric oxide are evolved, oxalic acid and nitrate of ammonia are formed, and there remains undissolved a bright yellow matter, which on being dried assumes an orange tint, and which is known as *Xanthoproteic acid*. It is devoid of smell and taste, although it slightly reddens moistened litmus paper. It is insoluble in water, alcohol, and ether. It dissolves in strong mineral acids, but is precipitated on the addition of water; with the alkalies it forms dark red soluble salts, and metallic salts throw down yellow precipitates. In a state of combination, the formula for this acid is $C_{34}H_{54}N_4O_{12}$; when free it contains two atoms of water.

The changes which occur in the production of this acid may be illustrated by the equation—



s. Chlorine and protein. On passing a current of chlorine gas through a solution of any of the protein-compounds, (albumen, fibrin, or casein,) a white flocculent precipitate is thrown down. After washing it, and carefully drying it at a temperature of 212° , Mulder deduced from it the formula $C_{30}H_{31}N_5O_{12} + ClO_3$. He termed it *chloro-proteic acid*. It appears from his investigations that the protein remains unchanged, but that a portion of the water is decomposed, and that its oxygen combines with chlorine to form chlorous acid (ClO_3) while its hydrogen combines with another portion of chlorine to form hydrochloric acid (HCl) which remains in solution in the water.¹

When ammonia is added to the chloro-proteic acid, the latter substance dissolves, and gives off a large amount of nitrogen. The solution must be evaporated to dryness, and then treated with warm water, which takes up a portion of the residue. On the addition of alcohol to this aqueous solution, a precipitate is thrown down, while muriate of ammonia remains in solution. This precipitate is composed of a substance of great physiological interest. Its formula² is

¹ That this compound is a chlorite of protein and not a chloride of tritoxide of protein seems certain from its analogy with a corresponding compound of gelatin.

² See Appendix, I, Note 2.

$C_{40} H_{31} N_5 O_{15} + HO$. Mulder originally termed it *oxyprotein*, but he has recently given it the more descriptive name of *tritoxide of protein*, without however intending to imply any thing more than that it contains three atoms more oxygen than protein. There is another and, in theory, a simpler method of obtaining this compound. When fibrin or albumen of inflamed or healthy blood, of serum of the blood, or of hen's eggs, is boiled with water, after four hours' boiling, principles are always obtained which are soluble in water, whilst the greater part remains undissolved. On repeating the ebullition every four hours with fresh water, fresh quantities of soluble matter are extracted, the insoluble portion becoming poorer in carbon, hydrogen, and nitrogen, but richer in oxygen, until the composition is finally constant. Moreover, the portion of albumen or fibrin soluble in water when evaporated, extracted with alcohol, and treated with cold water, is almost entirely soluble in it, and likewise contains less carbon, hydrogen, and nitrogen, but more oxygen than protein. The substances taken up by the alcohol are merely products of decomposition of the soluble portion of the fibrin or albumen. It is, moreover, the decomposition of this portion that gives rise to the ammonia that is produced on distilling albumen or fibrin with water.

The soluble matter taken up from the fibrin or albumen by prolonged ebullition is in every respect identical with the tritoxide of protein which we have already described; it exists, moreover, ready formed in the buffy coat of the blood. From whichever of these sources we procure it, whether from chloro-proteic acid, from albumen or fibrin, by prolonged ebullition, or from the buffy coat of the blood after a comparatively short ebullition, it possesses the same properties. It is soluble in cold water, but not in ether, alcohol, essential or fat oils, it has neither an acid nor alkaline reaction. It is always precipitated in the same manner from its aqueous solution by diluted nitric, sulphuric, hydrochloric, neutral and basic phosphoric, and tannic acids; by solutions of chlorine, bichloride of mercury, neutral and basic acetate of lead, nitrate of silver, sulphate of zinc, and peroxide of iron. It forms with metallic oxides a class of double salts, which are composed according to the formula $(C_{40} H_{31} N_5 O_{15} + MO) + (C_{40} H_{31} N_5 O_{15} + HO)$.

Tritoxide of protein is not precipitated by dilute acetic acid, neutral salts of potash and soda, chloride of barium, hydrochlorate of ammonia, nor by that very delicate test for protein, ferrocyanide of potassium. It dissolves gradually in solutions of potash, soda, and ammonia. When thoroughly dried, it occurs as an amber-coloured powder. Nitric acid converts it into xantho-proteic acid, a change which is not produced by the action of that reagent upon chloroproteic acid.

Let us now revert to the undissolved residue, which ultimately assumes a uniform composition expressed by the formula¹ $C_{40} H_{31}$

¹ See Appendix I, Note 3.

N_2O_{14} . It is this which is first formed from protein by the influence of the oxygen of the atmosphere. The other substance (trioxide of protein) originates from it by the addition of another equivalent of oxygen. In this respect albumen and fibrin give different results. Albumen, without going through this preparatory change like fibrin, is at once converted into trioxide of protein by ebullition, the insoluble portion which remains being unaltered albumen.

From the composition of this insoluble portion it has received the name of binoxide of protein. It exists ready formed in the buffy coat of the blood. Von Laer has obtained it from hair in the following manner. The protein is first thrown down by the addition of a little acetic acid to a solution of hair in potash. On the addition of a larger proportion of free acid, after the removal of the protein, another substance, previously in a state of solution, is thrown down. This is the binoxide of protein. Von Laer describes it as a bright yellow precipitate. After being carefully washed and dried it forms a black, glossy resinous mass, which on being pulverized forms a dark amber-yellow powder.

It is insoluble in water and alcohol, but dissolves perfectly in dilute acetic, hydrochloric, nitric, and sulphuric acids. It does not assume so strong a yellow colour as protein, when treated with nitric acid.

Ferrocyanide and ferridcyanide of potassium, and acetate of lead precipitate it from its acid solutions. It is soluble in potash and ammonia.

If the binoxide of protein be treated with chlorine there is formed, at a loss of one atom of nitrogen, and a gain of three of oxygen, a new substance $C_{40}H_{31}N_4O_{17}$, to which no name has yet been assigned.

In order to obtain these products of oxidation of protein by boiling fibrin in water, it is essentially necessary that there should be free access to the atmospheric air.

The products of the oxidation of protein occur constantly in the blood; they are formed in the lungs from fibrin, a substance which has been shown by Scherer to possess the property of absorbing oxygen when in a moist state. The fibrin, oxidized in the lungs is, according to Mulder, the principal, if not the only, carrier of the oxygen of the air; it is especially this substance from which the secretions are formed.

In inflammatory conditions, a considerably larger quantity of protein in an oxidized state, is contained in the body, than is found in a normal state.¹

¹ The examination of the foregoing facts leads to some very important conclusions. We see, for instance, that, by the ebullition of meat, protein is converted into two oxides, and is thus no more presented to the organism as a means of nutrition in the form of protein, but one part is converted into binoxide, which is hard and sparingly soluble, while another portion is changed into the soluble trioxide, and occurs in broth, extract of meat, &c. According to

These compounds (or at least one of them) are also found in pus, the substance termed *pyrin* being in reality tritoxide of protein; in false membranes, in cooked meat, and in vitelline substance; in the last-named substance we meet with a sulphuret of the binoxide of protein.

Mulder has recently obtained a third oxide of protein, represented by the formula $C_{44}H_{51}N_5O_{20}$, by boiling yeast in water. It occurs in a state of solution.

a. Potash and protein. On the addition of protein to a concentrated solution of potash, and submitting the mixture to ebullition, decomposition takes place, and a crystalline substance, two distinct extractive matters, and formate and carbonate of ammonia are produced. After the alkaline solution has been neutralized as completely as possible by sulphuric acid, the formic acid may be removed by gentle distillation.

On evaporating the mixture to about one third of its volume, the greater part of the sulphate of potash will separate in a crystalline state.

After its removal, the fluid which is of a reddish brown colour must be reduced to the consistence of an extract, and then treated with boiling alcohol, which will take up every thing except any sulphate of potash that may have escaped previous removal. As the alcoholic solution cools, *erythroprotid* is deposited in the form of a reddish brown extract. It is readily soluble in water, and in boiling, but not in cold, alcohol; and it is precipitable from its aqueous

Mulder, the interior of roasted meat undergoes a change analogous to that which is produced by ebullition. As the effects of ebullition upon albumen differ from those on fibrin, in evolving only the tritoxide of protein, boiled albumen must be perfectly distinct from boiled or roast meat as a means of nourishment.

The process of inflammation also appears essentially as a higher grade of oxidation. The albumen of the blood, which furnishes only tritoxide by ebullition, probably takes no part in the change: we may conclude that it is effected by the fibrin alone, which, as we know, absorbs oxygen from the air, and is with so much comparative facility converted into binoxide and tritoxide of protein. During the height of inflammation, there is a great excess of the oxides of protein in the blood; in a state of health they are, doubtless, present, but in much smaller proportions. Between these extremes there may be many intermediate states induced by different disorders. Respiration may consequently be regarded as a true oxidation of the blood, or rather of the protein; and in inflammation, in which the blood contains a greater quantity of binoxide and tritoxide of protein than in the healthy state, this body becomes more thoroughly oxidized. Hence it occurs that, in the acceleration of the act of respiration, in fevers, for example, inflammation so easily supervenes after any violent or sustained efforts. Every paroxysm of fever must necessarily cause the formation of a greater quantity of oxidized protein in the system, and every augmentation in the amount of oxidized protein must produce inflammation, which may, in its turn, determine fever. Hence also it happens that stimulating foods and drinks, which quicken the respiration, or cold air, which introduces more oxygen into the lungs, often give the first impulse to the development of inflammation in the organism. The buffy coat is formed when the oxides of protein predominate in the blood; when they accumulate in any particular part of the system, local inflammation is the result. In the latter case, morbid products, e. g. false membranes, &c., are evolved, which are found on analysis to be in a great measure composed of oxidized protein. Now inflammation must be combated by endeavouring to diminish the quantity of the tritoxide of protein, and to hinder its formation in the lungs. Venesection proves antiphlogistic by directly diminishing the tritoxide of protein: increased secretion of the alimentary canal indirectly produces the same effect by accelerating the change of substance in the body, and consequently also the consumption of a greater quantity of protein and its oxides.

solution by the salts of lead, silver, and mercury, of a rose-red colour; it is also precipitable by tannic acid. From an analysis of the combination of erythroprotid with oxide of lead, Mulder has estimated its composition¹ at C₁₃ H₁₂ N O₄.

Subsequently to the deposition of erythroprotid, *leucin* separates in a crystalline state. It occurs in brilliant plates or scales, somewhat resembling cholesterol. It crunches between the teeth, is inodorous and tasteless, and sublimes unchanged at about 340°. It contains no water of crystallization. It is soluble in water and in alcohol, but not in ether: its formula² is C₁₃ H₁₂ NO₄. According to Mulder it must be regarded as an integral constituent of protein. It combines with nitric acid and forms a crystalline acid to which the term nitro-leucic acid has been given.

We shall have occasion to revert to leucin in our observations on gelatin.

Protid is the term applied to the extractive matter that remains in solution after the removal of the *erythroprotid* and *leucin*. It is of a bright yellow colour, easily pulverizable, and soluble in water and alcohol without colouring them. It is precipitable by the basic acetate of lead, but not by any other metallic salts nor by tannin. The salts of lead serve to distinguish it from erythroprotid. If a mixture of these two substances be dissolved in water, the latter is precipitated by the neutral, the former by the basic acetate of lead.

Its formula³ is C₁₃ H₁₂ NO₄.

The action of caustic potash on protein is evidently very complicated. Mulder endeavours to show by the following formula how these metamorphoses *may* occur.

2 At. Erythroprotid	-	C ₁₃ H ₁₂ N ₂ O ₄	2 At. Protein	-	C ₁₃ H ₁₂ N ₂ O ₄
2 At. Protid	-	C ₁₃ H ₁₂ N ₂ O ₄	9 At. Water	-	H ₂ O
2 At. Leucin	-	C ₁₃ H ₁₂ N ₂ O ₄			
4 At. Ammonia	-	H ₂ N ₄			
2 At. Carbonic acid	-	C ₂ O ₄			
1 At. Formic acid	-	C ₂ H ₂ O ₄			
					C ₁₃ H ₁₂ N ₂ O ₄

According to Liebig, protein is produced by vegetables alone, and cannot be formed by animals, although the animal system has the power of converting one modification of protein into another; it is never found as *protein*, in nature; but occurs in the shape of albumen, fibrin, or casein, both in vegetables and animals. These modifications of protein are employed in the formation of the different tissues, each of which bears a simple relation to that substance, as will be seen by the following table:—

Albumen of the blood	-	= 10 F _T + S, P
Albumen of the egg	-	= 10 F _T + S P
Fibrin	-	= 10 F _T + S P

¹ See Appendix I, Note 4.

² Ib. Note 5.

³ Ib. Note 6.

Casein	-	-	-	$\approx 10 \text{ Pr} + 8$
Globulin	-	-	-	$\approx 15 \text{ Pr} + 8$
Muscular flesh	-	-	-	$\approx \text{Pr} + \text{H}_2\text{O} + \text{M}$
Arterial membrane	-	-	-	$\approx \text{Pr} + 2 \text{ H}_2\text{O}$
Mucus	-	-	-	$\approx \text{Pr} + 3 \text{ H}_2\text{O}$
Chondrin	-	-	-	$\approx \text{Pr} + 4 \text{ H}_2\text{O} + 2 \text{ O}$
Horny tissue	-	-	-	$\approx \text{Pr} + \text{NH}_3 + 3 \text{ O}$
Gelatinous tissue	-	-	-	$= 2 \text{ Pr} + 3 \text{ NH}_3 + \text{H}_2\text{O} + 7 \text{ O}$

We do not mean to assert that these formulæ represent the actual constitution of the respective tissues, but only that they give the proportion of elements actually present, and show how they might give rise to those tissues. Some of these tissues contain protein, or at least yield it by the action of potash, whilst others, as for instance the gelatinous tissues, although doubtless derived from protein compounds, do not contain it, and consequently cannot yield it.

Diagnosis of protein. Its insolubility in water, alcohol, and ether, and its precipitation from an acid solution by the ferrocyanide and ferridecyanide of potassium are sufficient.

2. *Albumen.*

This important modification of protein forms the white of eggs, and occurs in large quantity in all the animal fluids that contribute to the nutrition of the organism. It is also found in most of the animal solids, and in nearly all morbid products. We have already adverted to its existence in the vegetable kingdom.

Albumen is naturally soluble in water, and it is found dissolved in the serum of the blood, in vegetable juices, &c. But when it has once been submitted to a certain degree of temperature, or to the action of various chemical reagents, it assumes the coagulated state, and becomes insoluble in water.

Soluble albumen. Soluble albumen may be obtained in a solid form by evaporating to dryness, at a temperature not exceeding 120° , the serum of the blood, or white of egg. The dry mass is yellow, partially transparent, hard, and tough; it must be reduced to a fine powder, and treated successively with ether and alcohol. By these means we succeed in removing nearly all foreign bodies from the albumen, which when dried exhibits a white or pale yellow colour, is devoid of taste and odour, and presents a neutral reaction. If perfectly dry, albumen in this state may be exposed to a temperature of 212° without passing into the coagulated condition. When digested in cold water, it gradually swells up, and finally dissolves, forming a mucilaginous, colourless, and insipid fluid, which on being heated to 140° begins to give indications of coagulating: if the solution is very dilute, the temperature may be raised to 165° with the occurrence of this change, and when present in very small quantity the albumen may not separate till the fluid boils, or even until the ebullition has been prolonged for a short time.

When albumen is analyzed, it yields the same results as protein in regard to carbon, hydrogen, nitrogen, and oxygen, but it also contains a small quantity of phosphorus and sulphur, (less than 1% together,) which are absent in protein. According to Mulder's analyses,¹ the albumen of eggs may be represented by the formula C₄₀₀ H₅₁₀ N₅₀ O₁₂₀ SP + or 10 Pr + SP, which, as we shall presently see, is identical with the formula for fibrin.

The albumen of the blood differs from this, in containing one additional atom of sulphur; its formula is 10 Pr + S, P.

Most of the chemical observations on protein apply equally to albumen, and therefore without entering into any description of the various chemical changes that occur upon the addition of reagents, we shall simply notice the physical appearances presented on the application of the ordinary tests.

Albumen is precipitated from its fluid solutions by all the ordinary acids, with the exception of acetic, tartaric, and phosphoric (tribasic) acids; which not only do not precipitate it, but check the ordinary precipitation induced by heat. It is precipitated from its solution in these acids by ferrocyanide and ferridcyanide of potassium, the former of which yields a white, and the latter a yellow, precipitate. These precipitates are soluble in alkalies but not in acids. When these two substances are used as tests, their action may be impeded by the presence of free soda or its carbonate; the addition of a few drops of acetic acid is therefore always advisable in this case. Bichloride of mercury, and nitrate of the black oxide of mercury throw down whitish precipitates. Either of these tests will detect the presence of $\frac{1}{100}$ part of dry albumen. Precipitates of various colours and appearances are thrown down by sulphate of copper, nitrate of silver, the acetates of lead, protochloride of iron, alum, tannin, creosote, alcohol, &c.

The precipitates which the metallic salts throw down with albumen are usually mixtures of two distinct substances, one a compound of albumen with the acid, the other a compound of albumen with the metallic oxide; the former is usually somewhat soluble, the latter insoluble.

The alkalies and their carbonates form soluble compounds with albumen, and frequently require to be neutralized before the ordinary tests can be efficiently used.

The tests in most general use are heat, and nitric acid. When they both produce turbidity or a precipitate, the existence of albumen may be considered as proved.²

Coagulated albumen. Coagulated albumen may be obtained by submitting the white of egg or the serum of the blood to a temperature of from 160° to 180°; 167° according to Simon.

The coagulated mass must be then rubbed in a mortar, and suc-

¹ See Appendix I, Note 7.

² An apparent exception in the case of the urine will be subsequently noticed.

cessively digested in water, alcohol, and ether, until all substances soluble in those fluids are removed; it must then be carefully dried.

When obtained in this manner, it usually contains from 1 to $\frac{2}{3}$ of phosphate of lime, an earth which soluble albumen seems to have the power of dissolving.

In order to obtain it free from this impurity the following process may be employed. Coagulate albumen with dilute hydrochloric acid, wash the precipitate with water acidulated with the same acid, and then add so much cold water as may suffice to dissolve it. On the addition of carbonate of ammonia, coagulated albumen is separated as a flocculent, white precipitate. To remove any fat that may be present, it should be digested in hot alcohol or ether.

When dry, it is yellow and transparent; it swells upon being placed in water, but is only very slightly soluble in it. In its ordinary chemical relations it resembles protein.

Albumen always contains more or less salts, phosphate and sulphate of lime, chloride of sodium, and probably some lactates. Their amount is variously estimated by different chemists: the average is about 4 to 8%.

In the albumen of the egg Mulder found 0.9%, and in that of blood, 0.4% of sulphate of lime.

The development of the young animal in the egg of the bird during incubation affords a striking illustration of the physiological import of this substance. It is easily shown that the egg contains no nitrogenous compound except albumen. The albumen of the yolk has been proved, by the analyses of Bence Jones and Scherer, to be identical with the albumen of the white; and in addition to this the yolk only contains a yellow fat with traces of iron. Yet we see in the process of incubation, during which no foreign matter, except atmospheric air, can be introduced, or can take any part in the development of the animal, that feathers, claws, blood-corpuscles, fibrin, cellular tissue, and vessels are produced.

Diagnosis of albumen. It coagulates at 167°. It is not precipitated by acetic or dilute sulphuric acid, and from these acid solutions it is precipitated by ferrocyanide of potassium. Corrosive sublimate and nitric acid throw down copious deposits.

3. Fibrin.

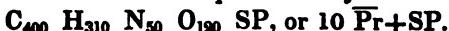
This modification of protein occurs in two forms, dissolved and coagulated. The former occurs in blood, lymph, chyle, juices of plants, &c., as long as these fluids form a part of the living organism; on their withdrawal from the influence of the vital force, the fibrin speedily coagulates. It is found in both these states in the animal and vegetable kingdoms.

The best method of obtaining it for chemical examination is either by briskly stirring newly-drawn blood with a little bundle of twigs, or else by shaking it in a stoppered bottle with a few bits of lead or

tin. The fibrin adheres to these substances in the form of a nearly colourless coagulum. This must be washed in cold water till it ceases to give off any colour whatever; it must then be treated with boiling ether, in order to remove the fat which is always associated with it.

When dried, it assumes a pale yellow colour, is devoid of taste and odour, and is insoluble in water, alcohol, and ether. When placed in water it sinks; it speedily absorbs a portion of the fluid, swells up, assumes its original bulk, and increases its weight threefold.

The composition of fibrin is represented by the formula¹



The observations which have been made respecting the action of acids and alkalies on protein apply equally to fibrin.

Fibrin is stated to have the power of decomposing binoxide of hydrogen catalytically with the evolution of oxygen and heat. According to Scherer this action is induced by fresh fibrin from any source, but not by boiled fibrin. This power is not possessed by albumen.

A concentrated solution of nitrate of potash dissolves humid fibrin in the course of twenty-four hours, and gives it the properties of albumen. (Denis.) This observation requires farther confirmation; it has failed in the hands of Simon and other chemists, and it is not impossible that the phenomena described by Denis were due to the presence of some uncombined potash.

The average quantity of fat associated with fibrin was found by Simon to vary from 2 to 4%, which agrees closely with the results of other observers.

Fibrin always contains a certain amount of salts, especially of the phosphate and sulphate of lime: the former seems to be chemically combined with it. The amount, according to Simon, lies between 1·5 and 2%.

Diagnosis of fibrin. Fibrin is distinguished by its spontaneous coagulation, by its insolubility in water, alcohol, and ether, and by its precipitation from acid solutions by ferrocyanide and ferridcyanide of potassium.

4. Casein.

This substance constitutes the most important ingredient in the milk of the mammalia. We have already shown that it also exists in vegetables.

Casein may be obtained with facility by either of the following methods.

a. Evaporate milk to dryness in the water-bath; triturate the solid residue and treat it with boiling ether, as long as it gives off any butter. When this ceases to be the case, remove the butter, and evaporate off the ether; dissolve the residue in water, and filter. On the addition of alcohol to the clear filtered fluid, the casein is sepa-

¹ See Appendix I, Note 8.

rated and thrown down. In order to remove any sugar of milk that may be entangled with the casein, the precipitate may be redissolved in water, and again thrown down by alcohol; if it be now collected and dissolved in water, it affords a tolerably pure solution of casein.

b. Casein may also be obtained by the addition of sulphuric (or any other) acid. Sulphate of casein is precipitated, which must be carefully washed in water, freed in the ordinary manner from butter, &c. and then digested with carbonate of lime. By careful and, if necessary, repeated filtration we obtain a clear solution, which however is not free from lime.

A solution of casein prepared according to either of these methods is possessed of little flavour; on the application of warmth it evolves a milky odour, and during evaporation it becomes covered with a skin of film, which on being removed is speedily renewed. This skin is due to the action of oxygen, for it does not form in an atmosphere of carbonic acid.

By a continuance of the evaporation we ultimately obtain a residue of dry casein. It appears as a brittle yellow substance. It does not admit of being perfectly dissolved in water, in consequence of a portion of it having assumed an insoluble condition during evaporation.

According to Mulder¹ casein is represented by the formula



The action of milk in the nutrition of young animals proves that casein is capable of being converted into albumen, and fibrin; while the production of milk in an animal fed on albumen or fibrin shows that these substances may be reconverted into casein.

The alkalies exert a similar solvent power over casein as over protein and its other modifications. The metallic salts also form similar double compounds. It differs from albumen, in being precipitated by *all acids*. The latter reagents must be applied cautiously, as casein is soluble in an excess of many acids.

On the addition of ferrocyanide or ferridcyanide of potassium to a perfectly neutral solution of casein, a slight precipitate is observed; if the solution is alkaline, there is no perceptible effect, but if it is first rendered acid by a little acetic or dilute sulphuric acid, a copious precipitate is thrown down by both tests.

The casein of cow's milk is thoroughly precipitated by the mucous membrane of the calf's stomach; on the addition of this reagent to woman's milk, imperfect coagulation sometimes occurs; in other cases no apparent action is produced; the coagulation is never perfect. In this case the mucous membrane of the child's stomach produces a more energetic effect than that of the calf. If a quantity of potash or ammonia be added to the milk, sufficient to give it a decidedly alkaline reaction, no coagulation is effected.

¹ See Appendix I, Note 9.

Rochleder has recently attempted to show that pure casein is a substance nearly insoluble in water; that the so-called soluble casein is a combination of casein with potash, soda, or lime; and that the coagulation of the soluble casein by acids, is nothing more than a separation of the casein, resulting from the combination of the acid with the base of the casein compound. In this manner, he explains how solutions of potash prevent coagulation, when added in very small quantity to milk, and why (especially in warm weather,) very slight causes are able to produce a coagulation of the milk; as only the smallest quantity of lactic acid is required to be formed, in order to neutralize the minute traces of soda, which are able to retain in a state of solution an enormous quantity of casein.

Coagulated casein is found in the milk, constituting the walls of the butter-vesicles. For the purpose of chemical investigation, it is best obtained by the addition of anhydrous alcohol to a solution of casein. When dried, it is hard, yellow, and transparent. In its chemical relations it closely resembles coagulated albumen.

The amount of ash left after the incineration of casein seems to vary considerably. Mulder estimates it at 3·8%, and Simon at 7%, in the casein of cow's milk. In casein from the milk of woman, Simon estimated it at 5%. Rochleder, whose experiments were made under the direction of Liebig, found that pure casein left only 0·3%. The ash contains phosphoric, carbonic, hydrochloric, and sulphuric acids, in combination with lime, and traces of magnesia and iron.

Diagnosis of casein. Casein may be distinguished from albumen by its not coagulating at 167°, and by the skin which forms on its surface during evaporation. It is precipitated by all dilute acids, and redissolves in an excess of the test. It is thrown down from its acid solutions by ferrocyanide and ferridicyanide of potassium. Casein of woman's milk is less perfectly thrown down by dilute sulphuric, lactic, and hydrochloric acids, than the casein of cow's milk.

Simon has obtained a modified form of casein from the crystalline lens, from tubercle, pus, and saliva.

It may be recognised as casein by the diagnosis which has been given, but it differs from human casein in its thorough precipitation by all acids; and from the casein of human and cow's milk by its greater solubility in hot alcohol of 0·915—0·925.

The globulin of Berzelius, which together with *haematin* forms the blood-corpuscles, is considered by Simon as a peculiar form of casein. Very little is known regarding it, farther than that it is a protein-compound. Mulder¹ represents it by the formula 15 $\text{Pr} + \text{S}$.

It must not be confounded with Lecanu's *globulin*, which is merely impure haematin mingled with some albumen.

¹ See Appendix I., Note 10.

² Ib. Note 11.

Pepsin, Ptyalin, Chondrin, Glutin, Pyin.

5. *Pepsin.* This name (from *πεπτος*, digestion) was given by Schwann, to a substance which constitutes the most essential portion of the gastric juice. The following directions for the preparation of pepsin are taken from Vogel's essay on the subject; they correspond in nearly every respect, with the method which was given by Wasmann, who has the credit of first obtaining it in an isolated state. The glandular membrane of the fresh stomach of the hog, is separated, and after being cut into small pieces, is treated with cold distilled water; after twenty-four hours' immersion, the water is poured off, and a fresh quantity added. This operation is repeated for several days, until a putrid odour becomes perceptible. The aqueous infusion thus obtained, is precipitated with acetate of lead, which causes a white flocculent deposit, containing the pepsin mixed with much albumen; this precipitate is diffused through the water, and must be decomposed by sulphuretted hydrogen. When the liquor is filtered, the solution contains pepsin and acetic acid, while coagulated albumen and sulphuret of lead remain on the filter. In order to obtain solid pepsin, the filtered liquid is evaporated to the consistence of a syrup, at a very moderate temperature (according to Wasmann, not higher than 95°), and absolute alcohol is then added to it. After some time a whitish bulky precipitate is formed, which is to be dried by exposure to the air; it then constitutes a yellowish viscid mass of a peculiar animal odour, and a disagreeable taste. Pepsin thus obtained, has an acid reaction, because it always contains a small quantity of acetic acid. This is most efficaciously removed by heating the pepsin for some hours in a salt-water bath; by which means a white powder, soluble in water, and possessing no acid reaction, is obtained. The action of a high temperature injures the digestive power of pepsin, but does not affect its chemical composition.

From Vogel's analysis¹ of this substance, it appears that it may be very nearly represented by the formula C₄₈ H₃₈ N₈ O₁₀. On comparing this with Liebig's formula for protein, it appears that pepsin may be formed from protein by the subtraction of two atoms of water, and the addition of two atoms of nitrogen.

The most remarkable property of pepsin is the power which its aqueous solution, when slightly acidulated, possesses of dissolving the protein-compounds. A solution containing only $\frac{1}{1000}$ part of pepsin, and slightly acidulated, will dissolve coagulated albumen in six or eight hours. This property is apparently destroyed by the alkalies.

Sulphuric, hydrochloric, and nitric acids, when added in very small quantity to a solution of pepsin, throw down white flocculi, which redissolve in an excess of the test: on the addition of still more acid the precipitate again occurs.

¹ See Appendix I, Note 12.

Acetic acid throws down a precipitate which redissolves in an excess of the test; no second precipitate is thrown down by the addition of more acetic acid.

Pepsin is thrown down from its aqueous solution by bichloride of mercury, acetate of lead, the sulphates of iron, sulphate of copper, and perchloride of tin. Ferrocyanide of potassium throws down no precipitate from an acidulated solution of pepsin.

Pepsin, which is precipitated from a concentrated aqueous solution by anhydrous alcohol, is said to lose its digestive power.

According to Liebig, pepsin as a distinct compound does not exist; he ascribes the solvent power of the gastric juice to the gradual decomposition of a matter dissolved from the membrane, aided by the oxygen introduced in the saliva. (Animal Chemistry, p. 109 et seq.)

Diagnosis. Pepsin is soluble in water, insoluble in absolute alcohol and ether; it is known by its precipitation by dilute acids, by the precipitate being redissolved in a slight excess of the test, and by the non-occurrence of a precipitate on the addition of ferrocyanide of potassium to the acid solution. It is farther distinguished from albumen by its being precipitable by acetic and dilute hydrochloric acids.

6. *Ptyalin.* This term has been applied to a peculiar animal matter that exists in the saliva. The following is the best method of obtaining it. Fresh saliva must be neutralized with acetic acid, and then evaporated on the water bath; the residue must be extracted first with alcohol,¹ and then with spirit. The ptyalin will remain undissolved amongst the protein-compounds, and must be extracted from them by the addition of water, in which it is readily soluble, and with which it forms a viscid fluid. The evaporation of this aqueous solution yields ptyalin free from all animal matters, but containing a trace of salts. When dry it is colourless, transparent, and brittle, devoid of odour, but with rather a sickly taste.

It is readily soluble in water, but is insoluble in alcohol and ether. It is precipitated from its aqueous solution by alcohol, but not by the mineral acids, metallic salts, acetic or tannic acid.

Our knowledge of this substance is by no means accurate; no analysis has ever been published, and there is no doubt that all the animal fluids yield an extract to water, which strongly resembles, if it be not altogether identical with, ptyalin.

Diagnosis. Ptyalin may be distinguished from the protein-compounds by its indifference to ferrocyanide of potassium; and from pepsin by its non-precipitation by dilute acids.

7. *Gelatin—Chondrin and Glutin.* Under the term gelatin we include the organic tissue of bone, cartilage, sinew, ligament, skin,

¹ The term *spirit* is used to denote alcohol of spec. grav. .833, which contains about 85% of anhydrous alcohol; by alcohol, anhydrous alcohol of spec. grav. .793 is implied.

cellular tissue, and serous membrane. All these substances dissolve by long continued boiling in water, and the solution on cooling assumes a consistent gelatinous mass. It is represented in various degrees of purity by glue, size, and isinglass. Gelatin does not exist as *gelatin* in the animal tissues, but is formed from them by the action of boiling water. Müller has shown that there are two (if not three) distinct forms of gelatin. To that which is obtained from the permanent cartilages, the cornea, fungous bones, &c. the term *chondrin* is given, while *glutin* includes those forms of gelatin which are obtained from skin, serous membrane, hoof, bone, tendon, fibrous and spongy cartilage, cartilage of bone, &c. As chondrin and glutin differ not only in the sources from which they are derived, but also in many of their chemical characters, we shall consider them separately.

Chondrin is most easily obtained by boiling any of the permanent cartilages, as for instance those of the ribs, larynx, or joints, for about twenty-four hours, in water: the solution must then be strained, in order to remove any coagulated matters, and allowed to gelatinize; it must then be dried at a low heat.

In this state it is hard and brittle, colourless and transparent. It sinks in cold water, and swells very much, without dissolving.

Scherer has deduced from his analyses the following formula¹ for chondrin, $C_{48} H_{40} N_6 O_{20}$, which corresponds numerically with $Pr + 4 HO + O_2$.

Its formula, according to Mulder, is $C_{320} H_{260} N_{40} O_{140} S$, or 20 ($C_{16} H_{13} N_2 O_7$) + S. When burned it leaves about $4\frac{1}{2}$ of phosphate of lime.

Chondrin is precipitated from its solution, and not redissolved in an excess of the test, by acetic acid, tannin, the neutral and basic acetates of lead, sulphate of iron, chlorine, iodine, and bromine. The following substances also give well-marked precipitates, which are, however, soluble in an excess of the test, alum, sulphate of copper, nitrate of silver, perchloride of iron, and nitrate of the protoxide of mercury. Creosote produces an immediate turbidity, and renders a solution of chondrin gelatinous in the course of twelve hours. Alcohol throws down chondrin from a concentrated solution, in the form of a white, viscid, and tenacious mass. Ferrocyanide and ferridcyanide of potassium throw down no precipitates when added to an acid solution of chondrin.

Glutin may be obtained in a state of purity from common glue, of which it forms the chief ingredient. On placing glue in cold water it absorbs moisture, and swells into a tremulous jelly, but does not dissolve. The cold water must be changed as long as it continues to take up any thing from the glue. The glue, after undergoing this purification, must be heated till it is perfectly fluid, and then strained through a cloth or coarse filter. It gelatinizes on

¹ See Appendix I, Note 13.

* Deduced from Liebig's formula.

cooling, and when dried represents pure gluten. In its physical characters it is nearly identical with chondrin, but is usually rather more coloured. It is represented by the formula¹ C₁₃H₁₀N₃O₅. (Mulder.) Scherer assigns to it the formula C₅₀H₅₃N₁₅O₃₀, which is numerically equal to 2 Pr + 3 NH₃ + HO + 70, but recent investigations tend to show that this formula gives an excess of hydrogen. When burned, gluten leaves a slight ash, consisting chiefly of phosphate of lime. By long continued boiling, gluten loses its power of gelatinizing; in this state its ultimate composition may be represented by the formula C₁₃H₁₄N₃O₁₁ or 4 (C₁₃H₁₀N₃O₅) + HO. In other words, it appears to be changed into a compound, in which four equivalents of gluten are united with one of water. If a stream of chlorine be passed through a solution of gluten, a compound of chlorous acid and gluten is obtained, which is analogous in type with the preceding substance. It is represented by the formula 4 (C₁₃H₁₀N₃O₅) + Cl O₃. This is the compound referred to in the note to page 19.

The most important test for gelatin (either gluten or chondrin) is tannin, which will precipitate it when diluted 5000 times. Three different compounds of gluten and tannic acid² have been discovered, and submitted to analysis; they are, however, individually of no particular importance in a physiological point of view. The extreme facility with which tannin precipitates gelatinous matters gives a clue to the medicinal action of astringent drugs on the human organism. They at once form insoluble compounds, (for tannin acts similarly on the protein-compounds,) and do not enter the blood; and this is the reason of their being comparatively innocuous. According to Mulder a less amount of tannin than is contained in one ounce of cinchona bark would, if conveyed directly into the blood, cause instantaneous death.

Acetic acid produces a slight turbidity, which speedily disappears on the addition of an excess of the test. Alum either produces no visible effect, or else throws down a very slight precipitate, which soon disappears, and the other salts, which have been mentioned as reagents for chondrin, yield no (or at most, very slight) precipitates with gluten. Alcohol and creosote act much the same as on chondrin, and no precipitate is occasioned by the ferrocyanide or ferridcyanide of potassium.

On boiling gluten in an excess of caustic alkali, till ammonia ceases to be developed, sugar of gelatin (glycicoll) and leucin are produced in the ratio of four parts of the former to one of the latter. In order to separate these substances, the alkaline solution must be saturated with sulphuric acid, evaporated to dryness, and the residue boiled with alcohol. The leucin being more soluble in alcohol than the glycicoll may be extracted from the evaporated alcoholic

¹ See Appendix I, Note 14.

² It must be remembered that tannin and tannic acid are synonymous terms.

solution by cold alcohol; the glycicoll will remain in an impure condition in the residue.

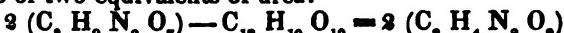
On treating glutin with concentrated sulphuric acid a colourless fluid is obtained, which, after prolonged boiling and saturation with carbonate of lime, yields, in addition to certain uninvestigated compounds, leucin and glycicoll. This method is stated by Mulder to yield a less quantity of glycicoll, in proportion to leucin, than the former.

Glycicoll crystallizes in colourless prisms from a solution in alcohol, and in rhombs from a spirituous solution. These crystals possess a very sweet taste, are perfectly neutral, resemble cholesterin in their appearance, dissolve in 414 parts of water and in 931 of alcohol.

The composition of glycicoll is represented by the formula¹



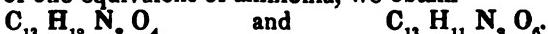
It is worthy of remark that on subtracting an equivalent of grape or diabetic sugar from two equivalents of glycicoll, we obtain the elements of two equivalents of urea:



The origin of *glutin* in the animal organism is still unknown. As no traces of it have ever been discovered in the vegetable kingdom, we cannot suppose that (like protein) it arises from that source. In all probability it is formed by the action of alkalies on protein; since we know that protein, submitted to such influences, yields products which in their chemical composition approximate closely to glutin, and that the blood is sufficiently alkaline to effect such, or similar, modifications.

In the hair, we find, associated with bisulphuret of protein Pr+2 S, a connecting tissue, $\text{C}_{13}\text{H}_{10}\text{N}_3\text{O}_7$, which differs from glutin, $\text{C}_{13}\text{H}_{10}\text{N}_2\text{O}_7$, simply by one atom of nitrogen.

Moreover protid, $\text{C}_{13}\text{H}_9\text{N}_2\text{O}_4$, and erythroprotid, $\text{C}_{13}\text{H}_8\text{N}_2\text{O}_4$, nearly resemble glutin in their composition, and both glutin and the protein-compounds yield leucin when treated with caustic potash. These facts render it in the highest degree probable, that glutin is formed in the organism, from the decomposition of protein by alkalies; much as protid and erythroprotid are produced in the laboratory. A reference to the symbolical illustration in page 23, will show that with every two equivalents of ammonia that are developed, there are produced one equivalent of protid, $\text{C}_{13}\text{H}_9\text{N}_2\text{O}_4$, and one of erythroprotid $\text{C}_{13}\text{H}_8\text{N}_2\text{O}_4$. If we add to each of these the elements of one equivalent of ammonia, we obtain



It only remains for us to assume that the oxygen which is continually acting on the blood in the lungs, yields three equivalents of oxygen to the former, and one to the latter of these substances, and we have from the protid,

¹ See Appendix I, Note 15.

$C_{12} H_{12} N_4 O_4 + O_3$ or $C_{13} H_{10} N_3 O_5 + 2 HO;$
and from the erythroprotid,

$C_{13} H_{11} N_3 O_6 + O$ or $C_{13} H_{10} N_3 O_4 + HO;$

that is to say, glutin and water may be supposed to be formed from protid and erythroprotid by the ammonia, which the alkali of the blood evolves from the protein-compounds, with the co-operation of the oxygen of the atmosphere, in the lungs.¹ In the present state of organic chemistry, it is impossible in most cases, to state with certainty how changes such as these take place; we can only indicate the possible, and the most probable methods. That the gelatinous tissues are evolved from protein-compounds, in some manner or other, cannot admit of a doubt. From what other source can they be derived in the chick, but from the protein-compounds of the egg?

That chondrin and glutin, the two principal forms of gelatin, are closely allied to protein, is sufficiently clear. They will not however yield protein, when acted on by potash; neither do they produce a purple colour with hydrochloric acid. Consequently they do not contain protein. Hence it is that animals fed exclusively on gelatin, die with the symptoms of starvation, for the gelatin cannot yield albumen, fibrin, or casein; and the animal system, although it has the power of converting one protein-compound into another, does not possess the power of forming protein from substances which do not contain it. Consequently blood cannot be formed from gelatin, and the animal soon dies. The probable uses of a mixed gelatinous diet for convalescents, are pointed out by Liebig in his 'Animal Chemistry,' pp. 98-9.

Diagnosis. Chondrin and glutin may be recognised by their property of gelatinizing on cooling, and by the energetic action of tannin on their solutions. Ferrocyanide of potassium added to an acidulated solution of these substances, serves to distinguish them from the protein-compounds; and either acetic acid or alum will suffice to distinguish chondrin from glutin.

8. Pyin. This term was applied by Gütterbock to a peculiar substance which occurs in pus, and which he isolates in the following manner. He precipitates the pyin, together with albumen, from pus, by the addition of strong alcohol. The precipitate is treated with water, which dissolves the pyin: any albumen that may be dissolved at the same time, can be coagulated by heat, and removed by filtration; and in this manner a tolerably pure solution of pyin is obtained. Vogel did not succeed in obtaining it; and from Simon's researches it would hardly appear to be a constant constituent of pus, and purulent sediments.

Pyin is soluble in water and aqueous alcohol, but not in alcohol

¹ The recent investigations of Enderlin, showing that there is no free alkali in the blood, but that its alkaline reaction is due to tribasic phosphate of soda, tend to throw considerable doubt on the ingenious hypothesis of Mulder, given in the text. It must also be remembered that leucin, protid, and erythroprotid have never yet been detected in the animal organism.

of .865, or stronger. It does not coagulate on boiling. When thoroughly dried it forms a gray powder, which does not admit of being perfectly redissolved in water. Acetic acid, tannin, and alum throw down precipitates, which are insoluble in an excess of the test. Ferrocyanide of potassium does not precipitate a solution of pure pyin; but on the addition of a little hydrochloric acid, a precipitate appears, which immediately vanishes on the addition of a little more of the acid. According to Mulder, it is identical with tri-toxide of protein.

Diagnosis of pyin. Pyin may be recognised by its reactions with acetic acid and alum. It may be distinguished from the protein-compounds (albumen, fibrin, casein,) in the same manner as pepsin and glutin. It differs from pepsin, by its acetic-acid precipitate not redissolving in an excess of the test, and from glutin and chondrin, by a similar behaviour on the part of the alum precipitate.

9. Extractive Matters.

After the removal of the protein-compounds from the animal fluids, there still remain certain salts, (lactates, chlorides, phosphates, and sulphates,) together with organic nitrogenous matter, which after evaporation remain as an amorphous mass. It is to this organic nitrogenous matter, after the salts have been removed by their appropriate solvents, that the term *extractive matter* is applied. It is as generally diffused over the whole system as the protein-compounds; we meet with it in blood, bile, milk, urine, mucus, pus, and all the soft tissues, and most abundantly in muscular flesh. Hence the extractive matter of flesh merits especial attention. The extractive matters from other sources, as from blood, urine, milk, &c., will be subsequently noticed, and their leading characters contrasted with those of our standard extractive matter, the extract of flesh.

For the purpose of thoroughly examining the extract of flesh in all its chemical bearings, Simon experimented on eight pounds of the thickest part of a leg of pork, which he freed as much as possible from sinew, fat, cellular tissue, and every thing that was not absolutely muscular flesh. It was then cut in small pieces, and cold water was poured over it. After being allowed to stand in water for some time, it was removed and boiled three successive times in fresh water. These boilings were collected, and a little fat skimmed off. The cold water in which it was first placed, was then boiled and mixed with the rest. The whole was then filtered, and appeared as a light yellow fluid, with a strong smell and taste of broth. This fluid was evaporated to the consistence of a thin syrup. After cooling, it did not gelatinize, and contained no glutin, or at most, a mere trace.

Alcohol was added to this thin syrup, until all the constituents insoluble in spirit, appeared to have separated, and deposited themselves at the bottom.

We thus separate the extractive matter into two distinct parts, one, soluble in water, but not in dilute alcohol, the other soluble in the latter menstruum.

The former, when evaporated at a gentle temperature, is of a brownish yellow colour, and is tolerably firm, tenacious, and tough; it is termed *water-extract*.

The latter must be evaporated to the consistence of an extract, and treated with from twelve to sixteen times its volume of absolute alcohol. The mixture must then be heated, and well shaken, so as to mix the alcohol with the deposited portion as thoroughly as possible. The alcoholic solution clears on standing, and assumes a yellow colour. It must be removed from the insoluble residue, and gently evaporated to a clear brown syrup, which, after cooling and standing for some time, assumes a solid form; it dissolves freely both in water and absolute alcohol. By repeatedly treating the insoluble residue with hot absolute alcohol, we remove all that is soluble in that fluid, and there is left a tolerably firm, tough, brown extract, which is soluble only in aqueous alcohol, and to which the term *spirit-extract* is given. We distinguish the portion which is soluble in absolute alcohol by the term *alcohol-extract*.

The extractive matter is thus separated into three distinct parts: these are—

- A. That which is soluble in water, but not in dilute alcohol: *water-extract*.
- B. That which is soluble in water and spirit, but not in anhydrous alcohol: *spirit-extract*.
- C. That which is soluble in water, in spirit, and in anhydrous alcohol: *alcohol-extract*.

A. The water-extract contains:

a. *Constituents precipitable by tannic acid:*

- (a) A matter not precipitable by neutral acetate of lead, but by basic acetate of lead and bichloride of mercury.
- (b) A matter precipitable by neutral and basic acetates of lead, and by bichloride of mercury.

b. *Constituents not precipitable by tannic acid:*

- (c) A gummy matter not precipitable by neutral acetate of lead, or bichloride of mercury, but by basic acetate of lead.
- (d) A matter freely precipitable by basic acetate of lead, and very slightly by neutral acetate of lead, and bichloride of mercury.
- (e) A matter precipitable by neutral and basic acetates of lead, but not by bichloride of mercury; the *Zomidin* of Berzelius.

B. The spirit-extract contains:

a. *Constituents precipitable by tannic acid:*

(a) A matter not precipitable by neutral or basic acetate of lead, but by bichloride of mercury.

(b) A matter not precipitable by neutral acetate of lead, or bichloride of mercury, but by basic acetate of lead.

(c) A matter precipitable by neutral and basic acetate of lead, but not by bichloride of mercury.

B. Constituents not precipitable by tannic acid:

(d) A matter rather indifferent towards reagents.

(e) A matter discovered and described by Chevreul; *Kreatin*.

C. The alcohol-extract contains:

a. Constituents precipitable by tannic acid:

(a) A matter precipitable by basic acetate of lead, and bichloride of mercury, but not by neutral acetate of lead.

(b) A matter precipitable by basic acetate of lead, and by an excess of bichloride of mercury, but not by neutral acetate of lead: it is crystalline.

B. Constituents not precipitable by tannic acid:

(c) A matter precipitable by basic acetate of lead, but not by neutral acetate of lead, or bichloride of mercury.

The substances *Aa*, *Ab*, *Ba*, &c., must be regarded as the proximate constituents of the three groups of extractive matters.

We shall arrange them in two classes, according as they are or are not precipitable by tannin.

Constituents of the extract of flesh, precipitable by tannin.

Aa exists in very small quantity in the water-extract: it may be distinguished from the protein-compounds by its indifference towards ferrocyanide of potassium; from pepsin and pyin, by its indifference to dilute acids; and from chondrin and glutin, by its aqueous solution not gelatinizing on cooling.

Ab may be distinguished in the same manner as *Aa*, from the protein-compounds, pepsin, &c.¹ It differs from *Aa* in being precipitated by protochloride of tin. When isolated, it is tolerably soluble in alcohol, although that fluid will not extract it directly from the water-extract.

Ba occurs in minute quantity in the spirit-extract. It may be distinguished from the preceding compounds by its solubility in spirit, and by its reaction with the acetates of lead.

These three substances, *Aa*, *Ab*, and *Ba*, differ so slightly in their reactions with various tests, that we may conclude that in all probability they are merely modifications of one and the same matter.

Bb may be distinguished from the preceding compounds by its indifference towards bichloride of mercury.

Bc is freely precipitated by the addition of sulphate of copper,

¹ The same observation applies equally to all the following constituents of extractive matter.

but the deposit, which is of a brownish colour, readily dissolves in an excess of the test. If just a sufficient quantity of the solution of sulphate of copper to dissolve the precipitate be added, and heat applied, a green precipitate forms, and the supernatant fluid is likewise green. Alum, cautiously added, throws down a brownish yellow flocculent precipitate, which dissolves in an excess of the test. Infusion of galls, added in small quantity, scarcely produces any turbidity in a solution of this constituent, but when added freely, a copious precipitate is deposited, which disappears on the application of heat, but returns as the solution cools. C_e may be distinguished from A_a , and A_b , by its indifference towards bichloride of mercury; from B_a , and B_b , by its behaviour with neutral acetate of lead, and sulphate of copper.

C_a is precipitable by protochloride of tin. This, together with the reactions it displays towards bichloride of mercury and infusion of galls, and its solubility in anhydrous alcohol, is sufficient to distinguish it from any of the preceding constituents.

The characteristics already mentioned are sufficient to distinguish C_b .

Constituents of the extract of flesh not precipitable by tannin.

A_c is remarkable for its indifference towards reagents. The only important tests have been already mentioned.

A_d is freely precipitated by bichloride of platinum; moreover the precipitate thrown down by basic acetate of lead is increased by heat.

A_e (*zomidin*) yields a very copious green or grayish green deposit, on the addition of acetate of copper. This precipitate does not dissolve in an excess of the test, but dissolves freely in acetic acid: on boiling this precipitate in caustic potash, it is rendered brown, while the supernatant fluid assumes a faint purple red tint. Infusion of galls renders a solution of zomidin slightly turbid, and after some hours a few flocculi are deposited, possibly in consequence of the existence of some impurity in the zomidin.

Berzelius considers that the savour of boiled and roasted meat depends on this constituent.

B_d yields a yellow precipitate to bichloride of platinum, a white deposit to the acetates of lead, and its solution is rendered slightly turbid by infusion of galls: the turbidity however disappears on the application of heat.

B_e (*kreatin*) is distinguished from all the preceding substances by its property of separating in rectangular crystals, and by its indifference towards the ordinary reagents.

C_c yields a copious white precipitate (which soon darkens) to nitrate of silver, and a chocolate-brown deposit to a solution of iodine.

There can be no doubt from the recent investigations of Mulder,

that the binoxide and tritoxide of protein occur in the constituents of the water-extract, and are probably identical with some of them.

The relative proportions of water-, spirit-, and alcohol-extract in flesh, blood, urine, and milk, appear to fluctuate. Simon found that, in the extractive matter of flesh, the water-extract predominates, while he could only obtain a very small amount of spirit-extract; in the extractive matter of blood, the water-extract is also the most abundant, but here the amount of alcohol-extract is less than that of spirit-extract; in the extractive matter of urine, the water-extract was the most scanty, and the alcohol-extract the most abundant; and in the extractive matter of milk, the alcohol-extract was the least of the three.

Extractive matter of blood. Simon gives the following directions for the exhibition of the extractive matter of blood. A quart of blood is heated to the boiling point, and a sufficient quantity of water is then added to reduce it to a thin pultaceous state. After standing for some time, it is strained, and the red fluid which passes through is again boiled. In this manner we obtain a clear yellow fluid, which no longer becomes turbid on the application of heat. On evaporation, this fluid assumes a dark green colour; and on further concentration to the consistence of a syrup, it changes to a brown tint. At the same time a film forms on the surface, which leads to the conclusion that a caseous matter (in this case globulin) is present. The extract exhibits an alkaline reaction.

When the extract has been reduced to the consistence of a syrup, it is treated with alcohol of .833, which throws down a copious brown precipitate. The clear alcoholic fluid is removed and evaporated. It forms a brown extract, which is devoid of the aromatic odour that is perceptible in the spirit-, and alcohol-extract of flesh. The residue is evaporated to the consistence of a thin extract, and then treated with absolute alcohol, which, when evaporated, leaves a very small amount of alcohol-extract.

Water-extract of blood. It is of a dark brown colour, and possesses a strong taste of salt. Its reaction is slightly alkaline, and there is nothing remarkable about its odour. On incineration, it leaves an alkaline ash, which effervesces on the addition of an acid.

The following are its most important chemical relations.

Acetic acid produces a turbidity which only disappears in a great excess of the test: ferrocyanide of potassium throws down a slight precipitate from the clear acid fluid, consisting of albumen.

Neutral and basic acetate of lead produce a copious brown precipitate; bichloride of mercury, even in excess, produces no apparent change. Infusion of galls induces merely a slight turbidity.

Spirit-extract of blood is of a dark brown colour, and a strongly salt taste. During evaporation it becomes covered with a coating of salts; and, after a certain degree of concentration, it solidifies, in consequence of the amount of the salts. It leaves a porous coal, which does not very easily burn to a white ash. This ash is strongly alkaline, and effervesces briskly on the addition of an acid.

The aqueous solution of the spirit-extract has a very feeble alkaline reaction.

Acetic acid produces a slight turbidity, which disappears on the addition of a considerable excess of the test.

Neutral and basic acetates of lead and infusion of galls produce copious precipitates; bichloride of mercury effects no apparent change.

Alcohol-extract of blood. When the alcohol in which this substance is contained, is evaporated to the consistence of an extract, and then warmed with ether, we obtain a greenish brown matter, which, after the evaporation of the ether, is soluble in water. Its amount is very minute; it has a feeble, alkaline reaction, and possesses a very disagreeable and nauseous taste. It is precipitated by perchloride of tin and nitrate of silver, but not by neutral or basic acetate of lead, bichloride of mercury, or infusion of galls.

Extractive matter of urine. The urine must be evaporated in order to precipitate the salts as much as possible, and then placed in a freezing mixture for the same purpose. When it is reduced to the consistence of a thick syrup, alcohol of .833 must be added to it as long as any additional precipitate is thrown down. This precipitate consists of salts, and contains hardly any extractive matter; it must be separated from the supernatant fluid, washed with alcohol of .833, dissolved in water, and precipitated again by alcohol. In this manner the spirituous solution assumes a yellow colour, while the salts are rendered colourless. By the evaporation of this yellow spirituous solution we obtain the *water-extract of urine*. It exists in very minute quantity. Infusion of galls produces hardly any marked effect, neither does bichloride of mercury; neutral and basic acetates of lead yield a copious precipitate.

Spirit-extract of urine is obtained by evaporating the spirituous solution to the consistence of a thick extract; it is then treated with a little anhydrous alcohol, and subsequently with ether. By shaking, and the application of a gentle warmth, the ether assumes a yellow colour, and a light brown matter separates; this must be washed in ether, and then treated with absolute alcohol, which throws down a brown extractive matter, while the alcohol assumes a nearly similar tint. This precipitate must be washed with absolute alcohol, dissolved in water, and evaporated. Its ash contains a considerable amount of chlorides. Infusion of galls, bichloride of mercury, and neutral acetate of lead do not affect its solution, but basic acetate of lead throws down a copious precipitate.

Alcohol extract of urine is obtained by the evaporation of the brown alcoholic solution referred to a few lines back. On the addition of anhydrous alcohol it is reduced to a yellow fluid, from which urea separates on slow evaporation. After the removal of this substance, we have the substance known as alcohol-extract of urine. Infusion of galls, bichloride of mercury, and neutral acetate of lead do not in-

fluence its solution; it is, however, precipitated by basic acetate of lead.

Extractive matter of milk. For the purpose of investigating the properties of this substance, Simon evaporated a quart of woman's milk (partly colostrum and partly during the early weeks of lactation) to about eight ounces, and he then removed the casein and butter by the addition of alcohol. After filtration, some water was added; the fluid was again evaporated to a residue of a few ounces, treated with alcohol of '833, and allowed to rest for some time. Sugar of milk of a slightly yellow colour was deposited, and the supernatant fluid had nearly the same tint. The latter was evaporated on the water-bath to the consistence of a syrup, and then treated with anhydrous alcohol, which reduced nearly the whole syrup to a solid consistence, while the alcohol above it, which contained the alcohol-extract, was hardly tinged yellow. The precipitate which is thrown down by the anhydrous alcohol contains the spirit-extract, and the water-extract is contained in the yellow-coloured sugar of milk.

The *water-extract of milk* is obtained by treating the precipitated sugar of milk with water, and allowing it to stand, well covered, for some days. In this manner we obtain a yellow, almost clear, and viscid fluid, standing above the white sugar of milk. On removing this fluid, and allowing it to evaporate spontaneously, a fresh quantity of sugar of milk is deposited; in fact, it appears impossible to remove *all traces* of this constituent of the milk from the water-extract. Alcohol throws down a yellow, glutinous, tough extract, which exhibits a feeble alkaline reaction towards litmus paper. This is the water-extract. When burned, it leaves a porous coal, from which a white alkaline ash, containing carbonates, may be obtained without much difficulty.

It is precipitated from its solution by infusion of galls, basic and neutral acetates of lead, but not by bichloride of mercury.

The *spirit extract of milk* is obtained from the precipitate which was thrown down by the anhydrous alcohol; it must be dissolved in a little water, and treated with alcohol of '833, which usually causes the separation of a little sugar of milk. The spirituous solution must now be evaporated to a very small residue, and some distilled water added, which produces a considerable turbidity, and ultimately causes a slight white precipitate. The nature of this precipitate remains doubtful. The spirit-extract is thrown down from its solution by infusion of galls and basic and neutral acetates of lead, but not by bichloride of mercury.

The *alcohol extract of milk* is obtained by the evaporation of the yellow anhydrous alcoholic solution that has been already referred to. It exists in very minute quantity, is of a yellow colour, and is not materially affected by infusion of galls, basic or neutral acetates of lead, or bichloride of mercury.

Ptyalin and pyin may be regarded as water-extracts of saliva and pus.

10. Colouring Matters.

I. THE BLOOD.

a. Hæmatin. This colouring matter is enclosed in thin sacs or vesicles, composed of a protein-compound, globulin: these vesicles exist in countless numbers in the circulating fluid, and are termed blood-corpuscles.

It has been generally assumed that this pigment exists in two distinct chemical states in arterial and venous blood, having in the former an excess of oxygen, in the latter an excess of carbon or carbonic acid. Mulder has, however, shown that its elementary composition is the same, whether obtained from arterial or from venous blood, and that it may be represented by the formula¹ $C_{44} H_{28} N_3 O_6 Fe$. Its composition seems likewise to be identical in all vertebrated animals.²

Various methods have been proposed for the exhibition of pure hæmatin. The following, adopted by Simon, is perhaps the simplest. Whipt and thoroughly dried blood must be pulverized, and its fat removed by repeated extraction with ether. It must then be boiled with anhydrous alcohol, and during the process of ebullition a quantity of sulphuric acid, diluted with cold alcohol, must be added, sufficient to communicate a marked acid taste to the mixture. In this manner a blackish brown solution of sulphate of hæmatin is obtained, which must be saturated with carbonate of ammonia. If the mixture be allowed to stand for some time, the sulphate of ammonia may be separated by filtration; the greater part of the alcohol must then be removed by distillation. This part of the process requires much caution, and the distillation must be conducted very gently, as the action of the fluid is often violent. The hæmatin, which is ultimately precipitated, must be carefully washed with water, in order to remove any traces of sulphate of ammonia. It must then be dried on the water-bath, pulverized, and treated with ether as long as it continues to communicate a dark tint to that menstruum. The ether takes up a certain amount of hæmaphæin associated with fat. The hæmatin must be boiled in distilled water, as long as it continues to give off salts and alcohol-extract, and then in alcohol, till every thing soluble in that fluid is removed. The substance that is left may be regarded as pure hæmatin.

We can only isolate it in this coagulated and insoluble condition. In the blood-corpuscles it exists in a state of solution.

When obtained by the process that we have just described, it is of a blackish brown colour, is devoid of taste and odour, is insoluble in water, ether, fatty and ethereal oils, and in bi-sulphuret of carbon.

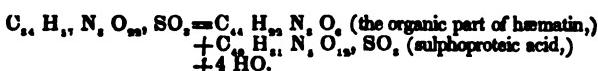
¹ See Appendix I., Note 16.

² Locardi examined hæmatin from human blood, and from that of the ox, domestic hen, duck, frog, carp, and mackerel. The only difference was in the proportion of peroxide of iron left when the hæmatin was incinerated.

It is usually stated to be insoluble in alcohol, but, according to Simon, boiling alcohol takes it up slightly. It is freely soluble in alcohol acidulated with sulphuric, hydrochloric, nitric, or acetic acid, and communicates a tint to that menstruum varying from a brown to a light red, according to the strength of the solution. On the addition of water the hæmatin gradually precipitates. Hæmatin dissolves freely in water or alcohol rendered alkaline by ammonia, potash, or soda: but the alkaline reaction is not in any degree neutralized by the hæmatin. On the application of a strong heat hæmatin swells up, gives off an animal odour, and burns with a clear flame. It leaves a voluminous coal, which is ultimately reduced to a dark red ash. When heated in a test tube it develops ammonia, and gives origin to a reddish empyreumatic oil.

Mulder has carefully examined the action of chlorine on haematin. He found that if a current of chlorine be transmitted through water containing haematin in suspension, the iron leaves the other elements, and forms a chloride of iron, while the atom of metal thus removed is replaced by six atoms of chlorous acid, and a compound is formed, which is represented by the formula $C_{16}H_{16}N_4O_4 + 6 ClO_2$.

During this process the red colouring matter is destroyed, and the new compound appears as a white flocculent precipitate. It must not, however, be assumed from this experiment that the red colour of the blood is dependent on the iron, for that constituent may be removed from the haematin without materially affecting its tint, as may be shown in the following manner. Let some dried blood be mixed with concentrated sulphuric acid, and after standing for some days let water be added. Hydrogen gas is evolved by the action of the acid on the dried blood, and sulphate of the protoxide of iron is formed. If the blood, after this process, be carefully washed, a mixture of alcohol and sulphuric acid will extract from it red haematin in combination with sulphoproteic acid, but perfectly free from iron. Van Goudoever has deduced the following formula for this compound:



Although this experiment affords conclusive evidence that the red colour of the haematin is not dependent on the iron, yet this metal is very firmly combined with the four organic elements of this constituent. Well prepared haematin may be submitted for several days to the action of dilute hydrochloric or sulphuric acid, without the iron diminishing in the slightest degree.

Hæmatin treated in this manner, left after incineration 9·49% of peroxide of iron,¹ the amount that is always yielded by well-purified hæmatin.

Peroxide Metallic
of Iron. Iron.
10.00 = 6.93
12.85 = 8.90

The condition in which the iron exists in hæmatin (whether as an oxide,¹ a carbonate, a carburet, or in the metallic state) has long been disputed.

The probability of its existence in a metallic state is strongly supported by the evolution of hydrogen that occurs when the clot is digested in sulphuric acid, and water is added; and Mulder suggests that this metal probably exists as an integral constituent of hæmatin, in just the same manner as iodine occurs in sponge, sulphur in cystin, or arsenic in the kakodyl series.

Numerous attempts have been made with the view to ascertain the proportions in which hæmatin and globulin combine, but the results have been very discordant. According to Berzelius, the hæmatoglobulin of human blood contains 100 parts of globulin, and 5·8 of hæmatin. Simon found the ratio to be 100 of globulin to 6·5 of hæmatin in the blood of a healthy young man, and 100 of globulin to 5·3 of hæmatin in the healthy blood of a stout girl. In disease, the variations are much greater. Simon has found as the limits 8·5 and 3·3 of hæmatin, corresponding to 100 of globulin.

Regarding the origin of hæmatin, it must clearly be generated in the organism, since it does not exist in the vegetable kingdom. Mulder conceives that it is generated from the normal constituents of the blood in the course of the circulation. Its destination also is obscure. In common with all the constituents of the body, it must be generated, consumed, and reproduced; but in respect to the actual metamorphoses that it undergoes in the organism, or their object, we are perfectly in the dark. Mulder suggests that the products of the decomposition of hæmatin may possibly be traced to the bilisulvin of the bile.

Diagnosis. Hæmatin may be known both in its coagulated and soluble state, by its colour. When combined with globulin, in the blood-corpuscles, it may be recognised by the microscope. In its coagulated state it may be recognised by its insolubility in water, alcohol, and ether.

b. Hæmaphæin. This term is applied by Simon to the brown colouring matter which seems to be associated with hæmatin in the blood of the vertebrata, and is apparently identical, or nearly so, with the yellow colouring matter described by Sanson.²

It may be distinguished by its solubility in water, alcohol, and ether, and by the intense brown-red colour that it communicates to its alcoholic solution. When exposed to heat on a platinum spa-

In 100 parts of hæmatin from arterial blood of ox, Mulder found,	9.60	= 6.66
" " from venous blood of ox " " .	9.82	= 6.75
" " from blood of ox, Simon found	11.50	= 7.97
" " from blood of sheep, Mulder found	9.30	= 6.45

¹ Iron is not separated from hæmatin by ammonia, potash, or soda; nor is its presence indicated by tannin or ferrocyanide of potassium, reagents which are so capable of detecting the presence of oxide of iron in ordinary cases.

² Journal de Pharmacie, Août, 1835, p. 420.

tula, it does not melt, but develops ammoniacal vapours, burns with a clear flame, and leaves a very trifling ash, which is perfectly free from peroxide of iron. Marchand remarks that hæmaphæin is nothing more than hæmatin modified by an alkali, just as O'Shaughnessy's *subruberin*, and Golding Bird and Brett's *chlorohæmatin* and *xanthohæmatin* are products of the action of nitric acid on hæmatin.¹

c. *Hæmacyanin*, or a blue colouring matter, has been detected by Sanson in healthy blood, by Lassaigne and Lecanu in the blood of icteric patients, and by Chevreul in the bile. Simon never succeeded in detecting it. For the method of isolating it, and for a description of its chemical characters we must refer to Sanson's paper. It is sufficient to remark that it is described as being insoluble in water, alcohol, and ether, but slightly soluble in boiling alcohol, from which, however, it separates on cooling. On the addition of ammonia to its alcoholic solution, a green colour is evolved, but on the addition of an acid, the blue colour is restored. It contains no iron.

II. THE BILE.

a. The most important colouring matter of the bile is that to which it owes its characteristic brownish yellow tint. It is termed *cholepyrrhin* by Berzelius, and *biliphæin* by Simon. We shall adopt the latter term. On the gradual addition of nitric acid to a fluid that contains this substance in solution, a very characteristic series of tints are evolved. The fluid becomes first blue, then green, afterwards violet, and red, and ultimately assumes a yellow or yellowish brown colour.

All attempts to isolate this substance from the bile, by chemical means, have failed; it is apparently decomposed by the processes that are adopted in the analysis of this complicated fluid. We sometimes, however, find it deposited in the form of a yellow powder, in the gall-bladder, or concreted, with a little mucus, constituting a biliary calculus.

In this manner we have an opportunity of examining its chemical reactions. Biliphæin is of a bright reddish-yellow colour, and is only slightly soluble in most fluids; it is devoid of taste and odour, and yields ammonia on dry distillation. Water takes up an extremely minute trace of biliphæin, just sufficient to communicate a faint yellow tinge. Alcohol dissolves more than water, but only a very inconsiderable quantity. Its best solvent is a solution of caustic potash or soda, both of which are more efficient than ammonia. On exposing this solution to the atmosphere, oxygen is absorbed,

¹ The discovery of the true nature of subruberin is due to Drs. Brett and Golding Bird, who showed that it is merely hæmatin mixed with a little albumen. Their chlorohæmatin is hæmatin partly oxidized by nitric acid, as Marchand observes; and their xanthohæmatin is at present supposed by Dr. G. Bird to be identical with some of the products of the oxidation of protein recently described by Mulder.

and the yellow colour becomes gradually green. On the addition of an acid to this yellow or green solution, there is precipitation of green flocculi which possess all the properties of chlorophyll, or the green colouring matter of leaves. In this state it is termed *biliverdin* by Berzelius. It is no longer biliphæin (or cholepyrrhin,) but a product of its metamorphosis.

The colouring matter of the bile may be separated from a composite animal fluid, by evaporation to dryness; by successive extractions with alcohol of '845, ether, and water; by dissolving the colouring matter in a solution of potash, and then precipitating it, as biliverdin, by hydrochloric acid.

Diagnosis. The action of nitric acid affords a certain test of the presence of biliphæin.

b. After the separation of the biliphæin, by conversion into biliverdin, another colouring matter remains, to which Berzelius has given the name of bilifulvin. It is a double salt of lime and soda, combined with an organic nitrogenous acid, to which the term bilifulvic acid has been applied. When isolated, this acid is insoluble in water and in alcohol, and separates in pale yellow flocculi when it is precipitated from an aqueous solution of its salts by a stronger acid. Whether bilifulvin is an actual constituent of the bile, or whether it is a mere product of metamorphosis, is unknown.

III. THE URINE.

a. Uroerthyrin. In certain pathological conditions (especially in intermittent fevers) the urine possesses an intensely red colour, and deposits a dark red precipitate. Proust, who was the first that carefully examined this class of sediments, discovered in them a peculiar acid, to which he gave the name of *rosacic acid*. He subsequently found that this acid was merely a compound of uric acid with a red colouring matter. This red colouring matter has been observed by Landered in the sweat from the axillary region of a girl with fever.

In order to isolate this pigment, we must boil a sediment of this nature in spirit, which will take up the colouring matter and a little uric acid. This uric acid must be removed by concentration and cooling, and then by evaporation to dryness, we obtain uroerthyrin. It yields a vividly scarlet powder, is devoid of odour, possesses but little taste, and is tolerably soluble in water and spirit: these solutions are faintly acid.

b. The blue and black pigments that have been described by various authors (Braconnot,¹ Spangenberg,² Granier and Delens,³ Marcket, Prout,⁴ &c.) and have received the names of *cyanurin* and *melanurin*, are not of sufficient importance to require any observations.

¹ Ann. de Chem. et de Phys. t. xxix. p. 252.

² Schweigger's Journal, t. xlvi. p. 457.

³ Ib. t. xxiii. p. 262.

⁴ Medico-Chirurgical Transactions of London, v. xii.

11. *Bilin.*

Bilin is the name given by Berzelius to the substance which he considers as the principal and most important constituent of the bile.

The following is the most simple process for its exhibition:⁴

Acidulate, perfectly fresh filtered ox-gall with a few drops of acetic acid, and precipitate it with neutral acetate of lead. The bilifellinic acid, which still remains in solution, must then be precipitated, as a plasty mass, by basic acetate of lead, and the filtered or decanted liquid, in which there is usually a little bilisulvin, must be decomposed by an excess of carbonate of soda. The precipitate is then to be extracted with absolute alcohol, and the soda carefully precipitated from this solution by dilute sulphuric acid. On evaporating the alcoholic solution to dryness, we obtain *bilin*.

The composition of bilin is not accurately determined. It is easy to show that it contains nitrogen, by heating it with an alkali, in which case it develops ammonia. Lehmann always found traces of sulphur in it.

Bilin forms a gummy, pale yellow mass, which when quickly dried and pulverized, yields a white powder, devoid of odour and possessing a singular sweetish-bitter taste, most perceptible at the base of the tongue and on the posterior fauces. Berzelius suggests that the sweetness may be owing to the admixture of a little glycerin.⁵ It is freely soluble in water and in alcohol, but not in ether; in fact it may be precipitated by ether from its alcoholic solution. When recently prepared, it is perfectly neutral. Heated to 212°, it begins to swell; at a higher temperature it becomes brown, develops a peculiar odour, and when inflamed, burns with a bright clear flame, leaving a porous ash.

An aqueous solution of bilin is not affected by acids, nor by earthy or metallic salts; neither does chlorine seem to induce any peculiar change. A concentrated solution of potash separates an oleaginous tough mass, (a compound of bilin and potash,) which is soluble in water and in alcohol.

Bilin is remarkable for the facility with which it undergoes metamorphoses. An aqueous or alcoholic solution *in vacuo* soon assumes an acid reaction. Its decomposition is accelerated by warmth, by the presence of organic matters, as mucus, &c., and more especially by the action of the mineral acids.

Metamorphoses of Bilin. Bilin and hydrochloric acid. On digesting bilin with dilute hydrochloric acid, five distinct substances are ultimately obtained, three of which are insoluble in water, and have received from Berzelius the names of *sellinic acid*, *cholinic*

⁴ Lehmann, Lehrbuch der Physiologischen Chemie, t. i. p. 309.

⁵ As the bile contains oleate, margarate, and stearate of soda, there is no difficulty in accounting for the presence of glycerin.

acid, and *dyslysin*; the remaining two being soluble in water, viz. *taurin* and hydrochlorate of ammonia.—The evaporation of an aqueous solution of the above mixture leaves as a residue a crystalline mass of taurin and hydrochlorate of ammonia; the latter may be removed by alcohol of 838, and the taurin may then be recrystallized from a solution in hot water.

Taurin forms colourless regular six-sided prisms, terminated by four or six-sided pyramids. It is hard, craunches between the teeth, has a cooling taste, but is neither bitter nor salt, dissolves in about sixteen times its weight of water at 60°, and is more soluble at a higher temperature. It is very slightly soluble in alcohol. It is dissolved without decomposition in concentrated sulphuric and nitric acids, and gives no reaction with the ordinary reagents. Its composition is represented by the formula $C_4NH_7O_{10}$. Hence, as Löwig remarks, it may be regarded as a combination of binoxalate of ammonia and water, for $C_4NH_7O_{10} = 2C_2O_3 + NH_3 + 4HO$.

On treating the resinous mass, which is insoluble in water, with alcohol, *dyslysin* is left, and the two acids are dissolved. *Dyslysin* dissolves with some difficulty in boiling alcohol, and falls again on cooling as an earthy powder. It has not been farther investigated.

Cholinic and *fellinic* acids are associated in the alcoholic solution. In many respects they closely resemble each other: they are almost insoluble in water, they dissolve in all proportions in alcohol, and they form nearly similar compounds with the alkalies, earths, and metallic oxides. Their salts of ammonia and baryta, however, differ in several respects, and by means of these reagents we can isolate the acids. If we evaporate a solution of their ammoniacal salts, cholinate of ammonia separates as a white soapy mass, while fellinate of ammonia remains in solution, and appears after due evaporation as a soft greasy, yellowish substance.

When an aqueous solution of cholinate of ammonia is decomposed by hydrochloric acid, cholinic acid separates in light white flocculi, which after drying form a brown pulverizable mass. It is only slightly soluble in ether. The cholinate of baryta is almost insoluble in alcohol.

Fellinic acid may be exhibited in a similar manner. It separates from its solution in snow-white flocks, and after drying forms a white, earthy, inodorous and bitter mass, which fuses at 212° without decomposition. In boiling water it undergoes fusion, and dissolves to a small extent; in this respect it differs from cholinic acid, which fuses, but is wholly insoluble in hot water. It is soluble in ether, and its baryta salt dissolves freely in alcohol.

Fellinic and cholinic acids possess the property of combining and forming acid compounds with undecomposed bilin, to which Berzelius has given the names of *bilifellinic* and *bilicholinic acids*.

Bilifellinic acid apparently exists *as such* in fresh bile: it may be obtained either from bile after the removal of mucus, colouring matters, and other acids, by neutral acetate of lead, or from pure bilin.

In either case we add a solution of basic acetate of lead, which throws down a flocculent precipitate which soon collects into a soft, tenacious, plastery mass. The salt of lead must be decomposed by carbonate of soda, and the soda-salt in its turn, by sulphuric acid: we thus obtain a very soft, almost oily, yellow mass, from which the free sulphuric acid must be removed by carbonate of lead, and free fellinic and cholinic acids, by ether. We then obtain bilifellinic acid in the form of a thick syrupy fluid soluble in every proportion of water, and possessing a bitter taste. If this acid be digested with oxide of lead, or decomposed by basic acetate of lead, a plastery bilifellinate of lead is again precipitated, while at the same time pure bilin is found in the supernatant fluid. Hence it appears that bilin combines with fellinic acid in more than one proportion. *Bilicholinic* acid appears to resemble bilifellinic acid in almost every respect.

A mixture of these two bilin-containing acids constitutes Demarçay's *choleic acid*,¹ and forms the principal part of Thénard's biliary resin. (Berzelius.)

On cooling bilin in a solution of caustic potash till ammonia ceases to be developed, we obtain, on evaporation, a clotty matter, which, when dissolved in water and treated with acetic acid, precipitates a peculiar acid, the *cholic acid* of Gmelin. It forms fine silky acicular crystals, of which the taste is at once sharp and sweet. It is slightly soluble in cold, but more so in hot water; it dissolves readily in alcohol: its solution reddens litmus. Most of the cholates are soluble, and possess a sweetish taste. Dumas assigns to this acid the formula² $C_{44}H_{38}O_{10}$.

There is no subject in the whole domain of animal chemistry that is more perplexing and intricate than the bile and its constituents. In the preceding pages, we have adopted the views of Berzelius, but upon this point, (cholic acid) he is very undecided. In the edition of his "Animal Chemistry," published in 1840, he states that he conceives it probable that cholic acid is produced by bilin alone, and that any fellinic or cholinic acids that may be simultaneously present, take no part in the metamorphosis. In his article "*Bile*," in Wagner's "Handwörterbuch," published two years later, he stated that bilin in a state of purity undergoes only a very slight change by boiling with hydrated potash, and that he could not convert it into cholic acid in that manner. Cholic acid certainly does not pre-exist in the bile.

Diagnosis of Bilin. Bilin may be detected by its peculiar taste. It is distinguished from the previous substances by its solubility in water and absolute alcohol, and by its insolubility in ether. Although absolutely pure bilin is said by Berzelius to be unaffected by metallic salts, basic acetate of lead and perchloride of iron throw down white precipitates from an aqueous solution; the latter, on the application of warmth, assumes a cinnamon tint: these reactions are probably owing to the presence of bilifellinic acid.

¹This substance is described in the chapter on the Bile.

²See Appendix I, Note 17.

12. *Urea.*

Urea forms the principal constituent of the solid residue of normal human urine. It is found in considerable quantity in the blood after extirpation of the kidneys, also in certain pathological conditions in which the renal functions are not properly discharged, as in diabetes, cholera, ischuria, and Bright's disease. That it does exist in healthy blood as a constant, although *very minute* constituent, has also been recently proved by Marchand and Simon. Rees has detected it in the liquor amnii and in milk; Kühn and Lehmann in bile and biliary concretions; Golding Bird in sweat; Wright in saliva, MacLagan in the serous effusion into the ventricles in certain forms of fever; and various chemists in dropsical fluids, &c.

Urea may be obtained from urine in a state of purity by any of the following methods.

a. The urine must be evaporated to the consistence of a syrup, and mixed when quite cold, with an equal volume of pure nitric acid of specific gravity 1·42. If the evaporation has been carried sufficiently far, the whole will form a thick crystalline mass, consisting of a compound of nitric acid and urea, which is sparingly soluble in nitric acid. All increase of temperature must be carefully avoided lest the nitric acid with the aid of heat, acting on the chlorides in the urine, should develop chlorine and nitrous acid, both of which, as we shall presently show, act powerfully in destroying urea. The impure crystals of nitrate of urea are to be carefully washed in dilute nitric acid, strongly pressed between folds of blotting paper, dried on a porous tile, redissolved in warm water, and neutralized with carbonate of lead. The residue, after evaporation, must be treated with alcohol. In this manner we obtain an alcoholic solution of urea, from which sulphuretted hydrogen, and animal charcoal, will suffice to remove any traces of lead and colouring matter: after due evaporation it will yield crystals of nearly pure urea.

b. O. Henry mixes the urine with basic acetate of lead, and then adds sufficient sulphuric acid, to convert all the acetates into sulphates. After filtration through animal charcoal the fluid will yield, on evaporation, crystals of nearly pure urea.

c. Berzelius recommends that the alcohol-extract of urine should be dissolved in water, treated with animal charcoal, filtered, and warmed to about 120°, and that then as much oxalic acid should be added as the warm fluid will dissolve. Crystals form of sparingly soluble oxalate of urea, which must be dissolved, filtered through animal charcoal, recrystallized, and decomposed by carbonate of lime.

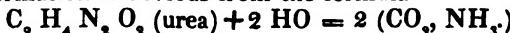
Urea may also be obtained artificially by the decomposition of certain cyanates. The following is the best method for obtaining it in this manner on a large scale. Twenty-eight parts of ferrocyanide of potassium, and 14 of peroxide of manganese, are to be thoroughly

mixed, and heated on an iron plate to a dull red heat. The mixture smoulders into a brown mass which contains cyanate of potash, carbonate of potash, and sesquioxide of manganese. When cold it is to be repeatedly digested in cold water, and the solution mixed with 20·5 parts of crystallized sulphate of ammonia dissolved in water. Sulphate of potash and cyanate of ammonia are formed; and this latter substance, on the application of a slight heat, is converted into urea. Sulphate of potash usually separates at once, in crystals; but, without stopping to remove them, we may evaporate the fluid on the water-bath to dryness, and remove the urea by a small quantity of water. On evaporating this aqueous solution to dryness, the urea may be extracted with boiling alcohol of 80 or 90°, whilst the sulphate of potash remains undissolved. The alcohol is allowed to evaporate, and the urea separates from it in crystals. In this manner a pound of ferrocyanide of potassium will furnish one third of a pound of pure urea.

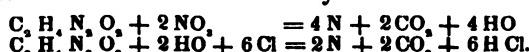
The composition of urea is represented by the formula¹ C₂H₄N₂O₂. It contains a larger proportion of nitrogen (46·728%) than any other organic compound.

Urea, when pure and in crystals, is white and transparent: when deposited from a concentrated hot solution, it is in the form of fine silky needles; but by very slow or spontaneous evaporation it separates in colourless flattened four-sided prisms of specific gravity 1·35. It is soluble in its own weight of cold, and in every proportion of hot water; in 4·5 parts of cold, and in 2 parts of boiling alcohol; it is slightly soluble in ether, about 1 part in 60, at a temperature of 62°.

It deliquesces in a very moist atmosphere only, and even then its chemical properties remain unchanged. In dry air it is perfectly permanent. It fuses at 250° into a colourless liquid, and is decomposed by a higher temperature into ammonia, cyanate of ammonia, and dry solid cyanuric acid. A concentrated watery solution may be boiled and preserved for a long time without any change, but if albumen, glutin, mucus, or especially ferment, should be present, it is speedily converted into carbonate of ammonia. The possibility of this transformation is obvious from the formula



With most concentrated acids it gives crystalline salts, especially with nitric and oxalic acids. It is not precipitated from its aqueous solution by metallic salts, ferrocyanide of potassium, or tannic acid. With hyponitrous acid it is instantly decomposed into nitrogen and carbonic acid gases, which are evolved in equal volumes; with chlorine it forms hydrochloric acid, nitrogen, and carbonic acid. These decompositions are rendered obvious by the formulæ



¹ See Appendix I, Note 18.

Compounds of urea. Nitrate of urea is obtained by the direct addition of nitric acid in excess, to a concentrated solution of urea. Its formula is $C_2H_4N_2O + NO_3 + HO$. It most commonly crystallizes in large colourless leaves, but sometimes in small solid prisms. It dissolves in eight parts of cold, but more freely in hot water. It is sparingly soluble in nitric acid, with which it may be boiled without decomposition. This salt effloresces with great rapidity.¹ 100 parts of nitrate of urea correspond to 48.945 of urea. (Regnault and Percy.)

Oxalate of urea is obtained by the mixture of concentrated hot solutions of urea and oxalic acid. Its formula is $C_2H_4N_2O_3 + C_2O_4 + HO$. It crystallizes in long slender plates or prisms, as the fluid cools, since it is much less soluble in cold than in hot water.

At a temperature of 61° water dissolves only 4.37g., and alcohol 1.6g., of the oxalate of urea. Oxalic acid displaces nitric acid from its combination with urea. 100 parts of oxalate of urea correspond to 62.564 of urea. (Berzelius.)

Sulphate of urea may be obtained by the double decomposition of oxalate of urea and sulphate of lime.

Hydrochlorate of urea has been formed by the direct combination of dry urea with hydrochloric acid gas. It is a very unstable compound, and when exposed to the air dissolves into a very acid liquid, from which hydrochloric acid is disengaged.

Lactate, hippurate, and urate of urea have been described by Cap and Henry; who in fact assert that in human urine the urea exists as a lactate. Pelouze has, however, disproved the existence of all these compounds.

Prout has examined certain compounds of silver and lead, in which the urea seems to combine with the oxides of those metals as bases. They are of no importance in a practical point of view.

The presence of urea modifies the solubility and crystalline form of certain salts; it causes common salt to crystallize in octohedra, instead of in cubes; but it has been observed that if these octohedra are dissolved in pure water they crystallize in cubes. This peculiarity affords a common microscopic test for the presence of urea.

Diagnosis of urea. Urea is distinguished by its solubility in water and in alcohol, and by its behaviour with nitric and oxalic acids.

¹ Nitrate of urea, when heated to about 316°, decomposes, and disengages a considerable quantity of carbonic acid and nitrous oxide, in the exact proportion of two volumes of the first to one of the latter; the residue consists of free urea and of nitrate of ammonia. Nitrate of ammonia and urea crystallize successively out of an aqueous solution of the residue. These changes are shown by the formula.

$4(C_2H_4N_2O_3NO_3HO) = 4CO + 2NO + 2(C_2H_4N_2O_2) + 3(NH_4NO_3HO)$

The nitrate of ammonia subsequently changes into water and nitrous oxide, and the urea into carbonic acid and ammonia.

During the decomposition of the nitrate of urea a new acid is formed in extremely minute quantities. It crystallizes in grayish white brilliant lamellæ, reddens litmus paper, and is very slightly soluble in water, which allows of its being separated from urea and nitrate of ammonia. Pelouze has assigned it the formula $C_2H_4N_2O_4$.

13. Uric acid.

Uric acid is a constituent of the urinary secretion in apparently all classes of animals; it is found in man and the carnivora, in graminivora (Fownes,)¹ in birds, amphibia, serpents, insects, and mollusca. It is the most common ingredient (in combination with a base) of urinary calculi and gouty concretions; it has been detected in the saliva (Wright,) in sweat (Wolf,)² and on the surface of ulcers in arthritic persons (Schönlein.)

Uric acid may be obtained in a state of purity, by the following process, from the excrement of the boa constrictor,³ which contains a very large proportion of uric acid and urea of ammonia. To powdered boa constrictor's excrement add an *equivalent proportion*, or slight excess, of caustic potash. (We assume that the excrement is entirely urea of ammonia in this calculation.) Boil in water in the proportion of 1lb. of excrement to 2 quarts of water till the mass is reduced to diffused gelatinous floccules, which speedily settle, leaving a dark-brown supernatant fluid. Remove this fluid by decantation or filtration, and wash the urea of potash, which is collected, with cold water. It must then be heated in water, and more caustic potash must be added, till the solution becomes clear. While still hot it must be poured into dilute hydrochloric acid, and allowed to stand. In this manner pure crystals of uric acid will be obtained.⁴ The slight excess of caustic potash used in the first instance seems to keep the colouring matter in solution.

Uric acid is represented by the empirical formula⁵ $C_5H_4N_2O_3$, or $C_{10}H_4N_4O_6$, or $C_{10}H_4N_4O_6 \cdot H_2O$; it is highly probable that it contains one atom of water in this state, and may be considered as a hydrate, $C_{10}H_4N_4O_6 \cdot H_2O$.

Uric acid crystallizes in fine scales of a brilliant white colour and silky lustre, is tasteless, inodorous, heavier than water, almost insoluble in cold, and very slightly soluble in boiling water.⁶ It is insoluble in alcohol and ether. It dissolves in dilute nitric acid, with the evolution of equal volumes of carbonic acid and nitrogen: on evaporating the solution a pink tint is produced, which, on the addition of ammonia in excess, changes to a purple-red colour. This

¹ London and Edinburgh Phil. Mag. xxi. p. 139.

² Dissertatio sist. casum Calculositatis; Tuling. 1817.

³ The excrements of the boa constrictor have been found by Prout to yield more than 90% of uric acid. (Annals of Philosophy, t. v. p. 413.) The excrements of the rattlesnake have been examined by Simon. He found in 100 parts of the dried residue—urea of ammonia, 31.1; urea of soda, with some chloride of sodium, 9.8; urea of lime, 1.4; phosphate of lime, 1.3. Although we have retained the term "excrements" in accordance with popular usage, the substance is in reality the urine of the serpent.

⁴ The various forms under which uric acid crystallizes are noticed under the head of *Urinary sediments*.

⁵ See Appendix I., Note 19.

⁶ According to Liebig, uric acid requires 15,000 parts of cold, and 1,932 parts of boiling water, for its perfect solution. It dissolves in all alkaline fluids, in solution of phosphate of soda and of borax, but not in solutions of the bicarbonates of potash or of ammonia.

is a characteristic test of the presence of uric acid. Boiled with peroxide of lead in water it is decomposed into oxalic acid and allantoin, and urea is separated.

Several of the compounds of uric acid, with the alkalies and alkaline earths, are of practical importance.

Urate of potash is a frequent constituent of urinary calculi: it may be obtained by boiling urate of ammonia with potash. On cooling the urate of potash yields a mass of very minute acicular crystals, or else separates in granules or scales. It dissolves in 140 parts of cold, and in 85 parts of boiling water.

Urate of soda may be obtained in a similar manner, or by boiling uric acid in a solution of borax. It is far less soluble than the former salt; one part of it requiring for its solution 372 parts of cold, and 124 parts of boiling water. In other respects it closely resembles it. It occasionally constitutes a very peculiar stellar form of deposit in the urine. Liebig has shown that uric acid dissolves with great facility in a solution of common phosphate of soda, that the fluid from being alkaline becomes acid, and that there are formed a urate of soda, and an acid phosphate of soda. It is in this condition that he supposes uric acid to exist in the urine.

Urate of ammonia, in a state of purity, invariably crystallizes in needles, but if a little chloride of sodium be added to its solution, we no longer obtain, on evaporation, a crystalline acicular deposit, but the peculiar amorphous form in which urate of ammonia occurs in urine. On the addition of chloride of sodium to water, in the proportion of 2·59 to 1000, the solubility of urate of ammonia is increased in the proportion of 1000 to 450, or is more than doubled. (Dr. Bence Jones, in Trans. of the Medico-chirurgical Society, 1844.)

According to Liebig, this salt requires for its solution 1727 parts of cold, and 243 parts of boiling water.

Urate of Magnesia may be obtained by the addition of sulphate of magnesia to a boiling saturated solution of urate of potash. On cooling, and after the fluid has been allowed to stand for some time, urate of magnesia is deposited in fine needles of a silky lustre, and arrayed in stellar groups. At 212° these crystals lose 5 atoms of water. Urate of magnesia dissolves in 3593 parts of cold, and 263 parts of boiling water.

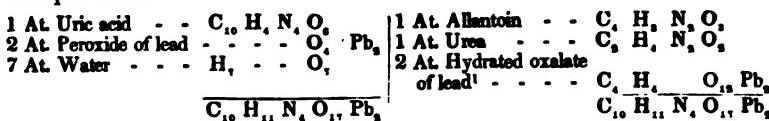
Urate of lime forms white glittering needles or leaves, which dissolve pretty readily in hot water, but are thrown down again on cooling.

Diagnosis of uric acid. Uric acid is distinguished by the form of its crystals under the microscope, by its insolubility in water and in alcohol, and by its behaviour towards nitric acid and ammonia.

The Metamorphoses of Uric Acid. Allantoin. One part of uric acid is boiled in 20 parts of water, and freshly prepared pe-

roxide of lead is gradually added to the boiling liquid, as long as its colour is observed to change. The hot liquid is then filtered and evaporated till crystals begin to form on its surface; on cooling they form in considerable quantity, and constitute *allantoin* or *allantoic acid*, while urea remains in the mother liquid, and oxalate of lead on the filter.

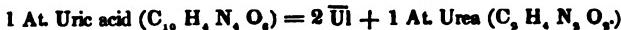
The following symbolical representation may elucidate this decomposition.



It is on this reaction that Liebig founds his theory of uric acid. He considers it to contain ready-formed urea and a hypothetical substance, for which he proposes the term *Uril* $\bar{U}l$, or cyan-oxalic acid.²

For 1 At. Uric acid ($C_{10}H_4N_4O_6$)—1 At. Urea ($C_2H_4N_2O_2$) = 2 (C_4NO_4) = 2 $\bar{U}l$.

Hence the rational formula for uric acid appears to be—

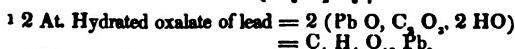
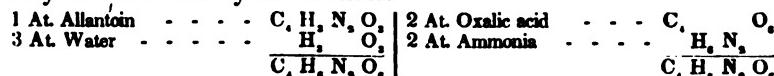


In the production of allantoin from uric acid, the urea is supposed to be set free, whilst the uril combines with oxygen and water in order to form oxalic acid and allantoin. The change may be illustrated in the following manner: $2\bar{U}l = C_4N_2O_4 = C_4O_4 + C_4N_2$.

By the addition of 2 at. oxygen to the former term, C_4O_4 , we obtain $2C_4O_4$ (oxalic acid,) and by the addition of 3 at. water to the latter, C_4N_2 , we obtain $C_4H_6N_2O_6$ (allantoin.)

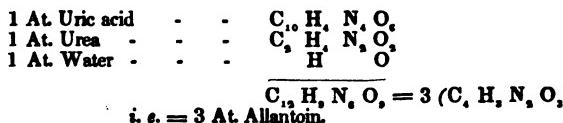
This substance *allantoin*, or as it is frequently termed *allantoic acid*, occurs ready formed in the allantoic fluid of the calf, from which it crystallizes spontaneously on cooling, when the fluid has been evaporated to one fourth of its volume. It then requires to be purified by recrystallization.

The crystals are colourless and transparent, tasteless and inodorous, and exert no action on vegetable colours. They are usually prisms of the right rhomboid system, have a glassy lustre, and at 68° are soluble in 160 times their weight of cold, but in a much less quantity of hot water; they dissolve in hot alcohol, but recrystallize as it cools. At a high temperature allantoin is converted by the caustic alkalies, and also by most concentrated acids (with the exception of nitric acid) into ammonia and oxalic acid. This change may be illustrated by the formula.



² This name is suggested by its constitution; for 1 at. Uril = C_4NO_4 = C_4O_4 , Cy, a formula that represents oxalic acid in which an equivalent of oxygen is replaced by one of cyanogen.

If we compare the composition of allantoin with that of uric acid and urea, we find that these substances bear a highly interesting relation to each other; if we add to one atom of uric acid, one atom of urea and one atom of water, we obtain a formula exactly corresponding with that of allantoin.



"According to this," as Liebig observes, "it is evident that the product of the secretion of the non-respiring foetus of the cow is, in a certain sense, identical with the products secreted by the kidneys of the breathing animals. Urea represents carbonate of ammonia from which the elements of two atoms of water have separated; allantoin represents oxalate of ammonia, from which the elements of three atoms of water have separated."

We now proceed to the consideration of a few of the most important products of nitric acid with uric acid.

Alloxan. One part of dry uric acid is gradually added to four parts of nitric acid of spec. grav. 1.42—1.5, by which it is dissolved with effervescence, and the production of heat. The whole liquid is soon converted into a solid crystalline mass of *alloxan*. Its formula is $C_8 H_4 N_2 O_{10}$. It is very soluble in water, reddens vegetable colours, and causes a purple stain on the skin. Its formation may be explained in the following manner. We have already shown (see *Urea*,) that urea is converted by hyponitrous acid into water, carbonic acid, and nitrogen. Hence we suppose that the 2 atoms of uril (bearing in mind that uric acid = $2\bar{U}l + 1$ at. urea,) take up the 2 at. of oxygen, which the nitric acid has given off in the formation of hyponitrous acid, and 4 at. of water, we obtain the formula of alloxan, for

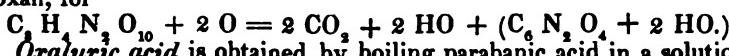


Parabanic acid is obtained by treating one part of uric acid, or one part of alloxan in eight parts of nitric acid, evaporating to the consistence of a syrup, and allowing it to stand for some time, when it yields colourless crystals which may be purified by recrystallization. Its formula is $C_6 N_2 O_4 + 2 HO$.

It is formed by the action of hyponitrous acid on the urea of the uric acid; the 2 at. of uril take up 4 at. of oxygen, and 2 at. of water, and yield 2 at. of carbonic acid, and 1 at. of hydrated parabanic acid: thus



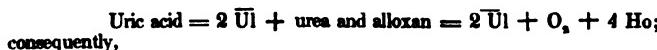
Or it may be regarded as produced by the action of oxygen on alloxan, for



Oxaluric acid is obtained by boiling parabanic acid in a solution

of ammonia. If the mixture be evaporated and allowed to cool, crystals of oxalurate of ammonia will separate themselves. On the addition of an acid to a concentrated solution of this salt, oxalic acid is separated as a crystalline powder. Its formula is $C_6H_3N_2O_7 + HO$. It is formed by the addition of 2 at. of water to the constituents of parabanic acid: it contains further the elements of 2 at. of oxalic acid, and 1 at. of urea, and by boiling in water is completely decomposed into free oxalic acid, and oxalate of urea.

Liebig observes that "when uric acid is subjected to the action of oxygen, it is first resolved into alloxan and urea; a new supply of oxygen acting on the alloxan causes it to resolve itself either into oxalic acid and urea, or into oxaluric and parabanic acids, or into carbonic acid and urea," (Animal Chemistry, p. 137.) The reactions which we have already given are sufficient to explain this statement. We have shown that—



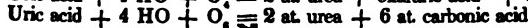
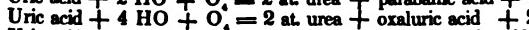
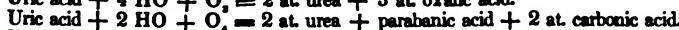
Moreover, Alloxan = urea + C_6O_6 (see their respective formula);

therefore, Alloxan + O_2 = urea + C_6O_6 = urea + 3 at. oxalic acid,

and Alloxan + O_2 = urea + C_6O_6 = urea + 6 at. carbonic acid.

Also, Alloxan + O_2 = parabanic acid + 2 HO + 2 CO_2 ,
 $=$ oxaluric acid + 2 at. carbonic acid.

Hence,



These formulæ express laws of much importance in urinary pathology; they show us that if an abundant supply of oxygen be given to the uric acid, carbonic acid and urea may be obtained; if a smaller quantity, oxalic acid and urea; and if none be given, the acid remains unchanged.

Murexid (Purpurate of ammonia.) The best method of exhibiting this substance is to evaporate a solution of uric acid in dilute nitric acid, until it acquires a flesh-red colour: after it has cooled to 160° a dilute solution of ammonia must be added, till the presence of free ammonia is remarked by the odour. The solution is then to be diluted with half its volume of boiling water and allowed to cool: it crystallizes in short four-sided prisms, two faces of which reflect a green metallic lustre. It is insoluble in alcohol; sparingly soluble in cold, but more readily in boiling water, on the cooling of which it crystallizes unchanged. It is soluble in caustic potash with a beautiful indigo blue colour, which disappears with the evolution of ammonia on the application of heat. The difference between the views of Prout and Liebig regarding this substance is, that the latter considers it a distinct principle, while the former regards it as a combination

of a peculiar acid (purpuric with ammonia.) Prout's view has been strongly confirmed by the researches of Fritzsche, which are published in the Transactions of the Academy of Sciences of St. Petersburg, for 1839.

The formula assigned to this substance by Liebig and Wöhler is $C_{12}H_8N_2O_8$. Fritzsche gives it the formula $C_{16}H_8N_2O_{11}$, or $C_{16}H_8N_2O_{10} + NH_4O$.

Murexan or purpuric acid is prepared by dissolving murexid in caustic potash by the aid of heat, which is to be applied till the blue colour disappears: dilute sulphuric acid is then to be added in excess. It falls in crystalline scales of a silky lustre; is insoluble in water and dilute acids, but is taken up by ammonia and the fixed alkalies.

If a solution of murexan in ammonia be exposed to the air, it acquires a purple-red colour and deposits crystals of murexid: with an excess of ammonia it again becomes colourless, and is then found to contain oxalurate of ammonia.

Its formula, according to Liebig and Wöhler, is $C_6H_4N_2O_8$; according to Fritzsche it is $C_{16}H_4N_2O_{10}$.

The substances which have been described are only a few of the products of nitric acid on uric acid; they have been selected as having a more practical bearing than the others. The following table exhibits the principal results of Liebig and Wöhler's admirable paper on this subject.

- (a) On treating uric acid with cold concentrated nitric acid, we obtain *alloxan*, $C_8H_4N_2O_{10}$ or $2\bar{U}I + O_2 + 4HO$.
- (b) On treating uric acid with cold dilute nitric acid, we obtain *alloxantin*, $C_8H_4N_2O_{10}'$ or $2\bar{U}I + O_2 + 5HO$.
- (c) On treating alloxan with sulphurous acid, we obtain *thionuric acid*, $C_8H_7N_3O_{14}S_2$.
- (d) On treating thionuric acid, or thionurate of ammonia, with hydrochloric, or sulphuric acid, we obtain *uramil*, $C_8H_7N_3O_6$ or $2\bar{U}I + NH_4 + 2HO$.
- (e) On treating alloxan with sulphuretted hydrogen, we obtain, first, alloxantin, and subsequently *dialuric acid*, $C_8H_4N_2O_8$ or $2\bar{U}I + 4HO$.
- (f) On warming uric acid in eight parts of nitric acid we obtain *parabanic acid*, $C_6N_2O_4 + 2HO$.
- (g) On boiling parabanic acid in ammonia, *oxalurate of ammonia* is generated, from which we can obtain *oxaluric acid*, $C_6N_2H_3O_7 + HO$.
- (h) On the addition of an alkali to a concentrated solution of alloxan we obtain *alloxanic acid*, $C_8H_4N_2O_8 + 2HO$.
- (i) By the precipitation of a solution of alloxan with boiling acetate of lead, we obtain *mesoxalic acid*, C_3O_4 .
- (j) By heating a solution of alloxan with ammonia, we obtain *mycomelinic acid*, $C_8H_6N_4O_5$.
- (k) On heating uramil with dilute sulphuric acid, we obtain *urameric acid*, $C_{16}H_{10}N_2O_{15}$.

- (l) On warming uric acid with nitric acid and saturating it with ammonia, we obtain *murexid*, $C_{12}H_4N_5O_9$.
 (m) On dissolving murexid in caustic potash and adding dilute sulphuric acid, we obtain *murexan*, $C_6H_4N_2O_5$.

14. Hippuric Acid.

Hippuric, or *urobenzoic acid*, is an ordinary, although not a constant, ingredient of the urine of the graminivora. It has been observed by Lehmann, Ambrosiani, and Reich, in the urine of diabetic patients, and Bouchardat has found it in the same secretion in certain anomalous cases to which he has applied the term "hippurie." Liebig has recently asserted that it is a constant ingredient of healthy human urine; and even if this statement be too general, there can be no doubt that it does very frequently occur in minute quantity in this secretion.

Hippuric acid is readily obtained by evaporating the urine of the horse or cow to about one tenth of its volume, and adding sufficient hydrochloric acid to give it a decidedly acid reaction. Yellow or brown crystals of hippuric acid are almost immediately deposited, which must be collected, dissolved in a hot solution of carbonate of soda, and filtered through animal charcoal. By the addition of hydrochloric acid to this solution, (which must be concentrated, if requisite,) we obtain tolerably pure crystals of hippuric acid.

This acid forms long transparent four-sided prisms, acuminated at the extremities; it is destitute of odour, and has a faintly bitter, but not an acid taste. It dissolves in about 400 parts of cold water, and in a much larger proportion in hot water, from which it recrystallizes on cooling. It is freely soluble in alcohol, less so in ether. A cold aqueous solution strongly reddens litmus. At a moderate heat, hippuric acid melts (without yielding water) into a colourless oily fluid, which, on cooling, solidifies into a crystalline milk-white mass. At a higher temperature the acid undergoes decomposition, and yields a crystalline sublimate composed of benzoic acid and benzoate of ammonia, while, at the same time, some red oily drops are produced, which develop a peculiar odour, resembling that of the Tonquin bean. Hydrocyanic acid is subsequently formed, and the previous odour is replaced by a bitter-almond smell. The action of perchloride of iron on this acid is worthy of notice. On the addition of this reagent to a solution of hippuric acid, a well marked yellow colour is produced; no such change is effected on the addition of this test to a solution of uric acid. On its addition to a solution of hippurate of potash, a copious orange-coloured deposit is thrown down, which, on the application of heat, forms a red resinous mass, soluble in alcohol, but insoluble in water; when added to a solution of urate of potash, a precipitate is likewise thrown down, which is at first of a brownish red colour, but rapidly becomes yellow.

The composition of this acid is represented by the formula¹ C_{18}

¹ See Appendix I, Note 20.

$\text{H}_3\text{NO}_2 + \text{HO}$. In its physical characters it strongly resembles benzoic acid, and there can be no doubt that these two acids have been often confounded: there is, moreover, a close analogy between them. They both belong to the benzoyl series, although the exact place of hippuric acid cannot be at present assigned to it with certainty. Oxidizing agents (as nitric acid, or sulphuric acid and benoxide of manganese) convert hippuric into benzoic acid; and a similar change occurs in the urine if it be kept for any time. Conversely, benzoic and cinnamic acids are converted in the organism into hippuric acid.¹

Hippuric acid forms soluble crystallizable salts with the alkalies and alkaline earths.

Diagnosis. Hippuric acid may be distinguished by its crystalline form, its solubility in alcohol, its behaviour when heated, and its reaction with perchloride of iron. Nitric acid will suffice to distinguish it from uric acid.

15. Uric Oxide.

Uric oxide, xanthic oxide, urous acid. This substance is a very rare ingredient in vesical calculi. It was discovered by Maracet, who gave it the name *xanthic oxide*; it has since been met with by Laugier, Stromeyer, and Dulk, and it is said to have been recently detected in guano, by Unger.

Urinary calculi which contain this ingredient are dissolved in caustic potash; the uric oxide is precipitated from the filtered solution by a stream of carbonic acid. It forms a white precipitate, which, when dried, constitutes a pale yellow hard mass. It is represented by the formula² $\text{C}_{10}\text{H}_4\text{N}_4\text{O}_4$. It differs from uric acid in containing two atoms less oxygen, hence the name of uric oxide. It dissolves in the alkalies, in small quantity in hot water, hydrochloric and oxalic acids, it is insoluble in alcohol and ether, and produces no effect on test paper. It dissolves also in concentrated sulphuric acid with a yellow colour, and no precipitate is caused by the addition of water to the solution. It is soluble in hot nitric acid *without effervescence*,³ and more slowly than uric acid. On carefully evaporating this solution, a lemon-yellow residue is left, which is not reddened by the vapour of ammonia, but which is dissolved with a reddish yellow colour by caustic potash, and leaves, on evaporation, a red residue. Muriate of ammonia throws down a yellow precipitate from the potash solution. Uric oxide differs from uric acid in being insoluble in a dilute solution of carbonate of potash; by this property

¹ Erdmann has sometimes found hippuric, and at other times benzoic acid, in the urine of the same horse. In all probability an excess of nourishment favours the production of this acid, for the urine of well-fed horses usually contains hippuric acid, while only benzoic acid can be discovered in the urine of horses employed for agricultural purposes: sometimes, however, the latter contains hippuric acid on some days and not on others, without any perceptible cause. For Liebig's theory of the origin of hippuric acid, see "Animal Chemistry," pp. 82, 140.

² See Appendix I., Note 21.

³ Dulk states that, in his case, the uric oxide did slightly effervesce.

these two substances may be separated from one another when they occur together.

Dulk conceives that he has effected the metamorphosis of uric oxide into uric acid. The yellow nitric-acid solution of uric oxide was evaporated on a watch-glass to a thick consistence. After a few days, small, hard, and transparent crystals appeared. A little of the portion which remained fluid, when heated on a platinum spatula over the flame of the spirit-lamp, assumed a blood-red tint, and in a few days the fluid which remained in the watch-glass, exposed to the atmosphere, underwent a similar change of colour. He considers the small crystals which were formed to consist of alloxantin; and, in support of his view, he alleges the following facts. Cold water poured over them assumes a red tint, but does not dissolve them; they are, however, perfectly soluble in boiling water, and, on the addition of ammonia to a hot concentrated solution, a reddish colour manifests itself, which disappears on cooling. On concentrating a portion of the solution to a few drops, mixing it with nitric acid, and then adding ammonia, a greenish salt separated itself.

Lehmann instituted a series of experiments with the view of obtaining uric oxide from uric acid by the action of deoxidizing agents, but he failed in his attempt.

16. Cystin.

Cystin, cystic oxide. Cystin is an occasional constituent of urinary calculi, and is sometimes found as a crystalline deposit in the urine. It may be obtained by dissolving a portion of one of these calculi in caustic potash, and adding acetic acid to the boiling solution. As the fluid slowly cools, the cystin separates in six-sided, colourless, transparent scales. It may also be obtained in crystals from a solution in caustic ammonia, if left to evaporate slowly. The scales are then thicker, and may be considered as regular six-sided prisms.

Cystin has an extraordinary composition. It contains 25.5% of sulphur. Its formula¹ is $C_6H_9N\ O_4S_2$.

It has neither an acid nor alkaline reaction; when heated it does not melt; takes fire with a bluish flame, and gives off a very characteristic odour; is very slightly soluble in water, and quite insoluble in alcohol; dissolves in dilute sulphuric, nitric, hydrochloric, phosphoric, and oxalic acids, the saturated solutions yielding, on gentle evaporation, salt-like compounds of cystin and the acid; these compounds separate in diverging crystalline needles, which have an acid taste, and are not very durable. Cystin dissolves readily in the fixed alkalies, and forms, on evaporation, granular crystals. It dissolves in caustic ammonia, but does not combine with it. Carbonate of ammonia is the best reagent for throwing it down from its acid solutions, as it does not dissolve cystin. It may be removed from an alkaline solution by acetic, citric, or tartaric acid, with none of which it enters into combination: acetic acid is generally used.

¹ See Appendix I. Note 22.

Diagnosis of cystin. Cystin may be recognized by the peculiar crystalline form¹ (six-sided plates) in which it separates from its solutions; by its insolubility in water and alcohol; by its behaviour towards acids; and by its peculiar odour on burning. Its crystalline form and its behaviour towards acids distinguish it clearly from uric acid: these tests, as well as its solubility in hydrochloric and oxalic acids distinguish it from uric oxide.

CLASS II. NON-NITROGENOUS CONSTITUENTS.

1. *Animal Sugars.*

a. *Sugar of milk* is an integral constituent of the milk of the mammalia, and is a very rare ingredient of any other fluid. It has never been detected with certainty in the blood; although Simon was led to believe, from the taste, and the carbonization with sulphuric acid, that he had once separated it from calves' blood. Prout once found it in the liquor amnii of a cow, but this is the only instance in which it has been detected in that fluid. A more remarkable case is recorded by Koller,² who removed a milky-looking fluid from between the tunics of the testicle, which contained sugar of milk.

Sugar of milk may be obtained by evaporating whey to the consistence of a syrup, and setting it aside for some weeks in a cool place. Granular crystals of sugar of milk will be spontaneously deposited. In order to procure them in a state of purity they require several solutions and recrystallizations.

Sugar of milk is white, and crystallizes in right four-sided prisms, usually terminated by four-sided pyramids, which are semi-transparent, and have a spec. grav. 1.543. It dissolves in 5 or 6 parts of cold water, and in 2.5 parts of boiling water, without forming a syrup. A solution communicates a more decidedly sweet taste to the tongue than the crystals themselves. Sugar of milk is unaltered by the air, loses nothing at 212°, and is insoluble in alcohol and ether. At a high temperature it fuses, swells up, and develops a sweetish but very pungent odour. It burns with a palish blue flame, and leaves, after incineration, an ash consisting of the carbonates, sulphates, and phosphates of lime and potash, amounting to about 1% of the sugar. According to Simon, the sugar of woman's milk does not melt on being exposed to a high temperature, but only becomes tough and fibrous.

By digestion in dilute sulphuric or hydrochloric acid, or in acetic or citric acid, sugar of milk becomes converted into sugar of grapes.

¹ I once observed an amorphous deposit of urate of ammonia yield, on the addition of acetic acid, perfectly regular hexagons. This form is also depicted by Rigby, in his work on Dymenorrhœa.

² This fluid contained in 1000 parts: Butter 16.49—casein 20.31—sugar of milk 31.50—chloride of sodium—2.78—lactate of soda 0.74—sulphate of potash 1.51—sulphate of soda 0.37—carbonate of lime 0.38—carbonate of magnesia 0.47—phosphate of magnesia 0.89.—(Wagner's Handwörterbuch, t. i. p. 25.)

By nitric acid it is decomposed into mucic,¹ oxalic, saccharic, and carbonic acids.

On the addition of casein, animal membrane, diastase, &c. to a solution of sugar of milk, lactic acid is formed and the fluid begins to ferment.

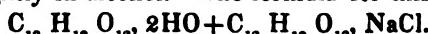
Crystals of sugar of milk may be represented by the formula $C_{12}H_{12}O_{12}$. At a temperature of 212° the crystals lose 11.9 g., or two equivalents of water. Consequently the formula for anhydrous sugar of milk is $C_{12}H_{10}O_{10}$.

β. Diabetic sugar exists in the blood and urine, and occasionally also in the sweat² of persons suffering from diabetes.

It may be obtained by adding basic acetate of lead to the urine, filtering, precipitating any excess of lead by sulphuretted hydrogen, evaporating, extracting the syrupy residue with alcohol, and allowing the alcoholic solution to crystallize. It requires several crystallizations to obtain the sugar in a state of purity. Diabetic sugar usually crystallizes in wart-like knots, or plumose groups, of minute, rhombic, transparent crystals. It is white, devoid of odour; in sweetness and in solubility in water³ it ranks between cane sugar and sugar of milk. It is more soluble in dilute alcohol than sugar of milk, but is insoluble in absolute alcohol and ether.

Diabetic sugar in a crystalline state is represented by the formula $C_{12}H_{14}O_{14}$; in this condition it contains two equivalents, or $9\frac{2}{3}$ of water, so that its correct formula is $C_{12}H_{12}O_{12}+2HO$. It is identical in its chemical composition with sugar of grapes.

Diabetic sugar forms a beautiful crystallizable compound with chloride of sodium. On saturating diabetic urine with common salt, and leaving it to spontaneous evaporation, crystals three fourths of an inch in diameter may be obtained. They are not very regular in their form, but most of them are six-sided double pyramids. These crystals are hard, easily pulverizable, transparent, of a combined saltish and saccharine taste, and dissolve in about 3·7 parts of cold water, and slightly in alcohol. The formula for this combination is



*Tests for Diabetic Sugar.*⁴ *a. Hünefeld's test.* Place 4 oz. of the suspected urine in a glass exposed to the sun's rays, and add about 6 drops of a tolerably strong solution of chromic acid. In a few minutes, if sugar be present, the mixture, previously orange red, becomes brownish, and soon after assumes a bistre-brown colour.

¹ It is worthy of remark that sugar from different sorts of milk yields varying quantities of mucic acid.

² A case in which sugar was detected in the sweat of a diabetic patient is recorded by Name, Rhein. Corresp. Blatt. 1842, Nr. 6.

³ Simon found that one part of diabetic sugar dissolved in 1·3 of water at 53° .

⁴ The following observations are principally taken from an excellent paper, by Dr. G. Bird, on the detection of a diabetic state of the urine, in the London Medical Gazette for 1843. We have omitted to notice the test afforded by the rotatory power of a solution of sugar on a ray of polarized light, as it has been shown by Dr. Lesson to afford very fallacious results. (Memoirs of the Chemical Society, Part 7.)

These changes take place much more quickly if the mixture of urine and chromic acid be gently warmed before exposure to light.

This test depends for its action upon the deoxidizing power of the sugar, by which the chromic acid is reduced to oxide of chromium; for, after warming the mixture, the addition of a few drops of *liquor potassæ* produces a copious deposit of the green oxide.

There is an important objection to this test which renders all its indications liable to serious fallacy, depending upon the fact, that all urine containing a normal proportion of colouring matter deoxidizes chromic acid; and consequently urine, whether saccharine or not, will partially convert this acid into the oxide. This change certainly does not occur so readily in non-saccharine urine as in a diabetic state of that fluid, but still is sufficiently marked to prevent Hünefeld's test being regarded in any other light than a fallacious one.

b. Runge's test. Allow a thin layer of the suspected urine to evaporate on a white surface, as the bottom of a white plate, and, whilst warm, drop upon the surface a few drops of sulphuric acid, previously diluted with 6 parts of water. With healthy urine, the part touched with the acid becomes merely of a pale orange colour, from the action of the latter upon the colouring matter of the urine; whilst if sugar be present the spot becomes deep brown, and soon black, from the decomposition of sugar by the acid, and consequent deposition of carbon. This test is stated to be so delicate, that 1 part of sugar dissolved in 1000 of urine can be readily detected; and even when mixed with 2000 parts the indications are tolerably distinct.

According to Dr. G. Bird, the presence of albumen causes the acid to yield a tint nearly resembling that produced by sugar.

c. Moore's test depends on the conversion of diabetic sugar into brown melassic (or perhaps sacchulmic acid) under the influence of a caustic alkali. Place in a test tube about two drachms of the suspected urine, and add nearly half its bulk of *liquor potassæ*. Heat the mixture over the spirit-lamp, and allow it to boil for a minute or two; the previously pale urine will become of an orange-brown or even bistre tint, according to the proportion of sugar present. This reaction has been long known, but Mr. Moore deserves the credit of bringing it prominently forward.

d. Trommer's test. Add to the suspected urine contained in a large test tube, a few drops of a solution of sulphate of copper; a very incon siderable troubling generally results, probably from the deposition of a little phosphate of copper. Sufficient *liquor potassæ* should then be added to render the whole strongly alkaline; a grayish green precipitate of hydrated oxide of copper falls, which, if sugar be present, wholly or partly redissolves in an excess of the solution of potash, forming a blue liquid, not very unlike the blue ammoniuret of copper. On gently heating the mixture nearly to ebullition, the copper falls in the state of suboxide, forming a red and copious precipitate. If sugar is not present, the copper is deposited in the form of black oxide.

This test is founded on a fact long known, but not previously applied to the detection of sugar, of the power possessed by some organic matters of reducing oxide of copper, as well as some other oxides, to a lower state of oxidation. It certainly is the most delicate of all the chemical tests hitherto proposed for the detection of sugar in the urine, and will readily detect it in diabetic urine, even when very largely diluted.

It is important in using this test that no more of the solution of sulphate of copper be used than is sufficient to afford a decided precipitate on the addition of the *liquor potassæ*. If this precaution be not attended to, a part only of the black oxide will be reduced to red suboxide, unless a very large quantity of sugar is present, and thus the indications afforded by this test will be rendered indistinct.

e. Fermentation test. The development of the vinous fermentation on the addition of a little ferment or yeast to a fluid, has long been applied as a test for the detection of sugar. It was successfully employed by Professor Leopold Gmelin of Heidelberg¹ for the detection of sugar in the animal fluids after the ingestion of amylaceous food. Dr. Christison has the merit of particularly suggesting the application of fermentation for the discovery of a diabetic state of the urine.

When a little yeast is added to healthy urine exposed to a temperature of about 80°, no other change occurs for some time, except the development of a portion of carbonic acid mechanically entangled in the yeast. When sugar is present in the urine thus treated, it soon becomes troubled, a tolerably free disengagement of bubbles of carbonic acid takes place, and a frothy scum forms on the surface of the fluid, which evolves a vinous odour. These changes take place with great rapidity, even when the quantity of sugar present is very small. If the evolved carbonic acid is collected, the quantity of sugar in the urine may be determined by measuring it, as a cubic inch² of the gas very nearly corresponds to a grain of sugar.

In the absence of a mercurial trough, the carbonic acid may be determined by the increase of weight³ of Liebig's bulb-apparatus, charged with a solution of potash.

f. Test afforded by the growth of the torula. If urine containing the smallest proportion of sugar be exposed for a few hours to a temperature above 70°, and a drop taken from the surface be examined under the microscope, numerous very minute ovoid particles will be discovered. In the course of a few hours more they become enlarged, and appear as distinct oval vesicles, which rapidly become developed into that species of confervoid vegetation, to which the term *torula* has been applied.

¹ Recherches Expérimentales sur la Digestion. Paris, 1826. Part I. p. 202.

² 100 cubic inches of carbonic acid gas correspond with 106·6 grains of diabetic sugar.

³ 100 grains of carbonic acid indicate 225 grains of diabetic sugar. The gas must be passed through a tube containing chloride of calcium.

2. *Fats.*

Under the name of "fats," we include various non-nitrogenous compounds, which are insoluble in water, but soluble in hot alcohol and ether.

Some of these fats possess the property of being decomposed by strong bases, especially by the alkalies, and by oxide of lead; in this case one of the two principal constituents separates itself, while the other (an acid) combines with the base, forming a soap with the alkalies and a plaster with oxide of lead. Hence it follows that those fats which, on account of this property, are termed saponifiable, are, like the salts, formed of an acid and of a base; these acids and their bases being themselves the oxides of compound radicals, probably of hydro-carburets.

There are other fats which cannot be decomposed in this manner: they are termed non-saponifiable fats.

We shall commence with the consideration of the former class, the *saponifiable* or *true fats*.

a. *Fatty Bases.* We are acquainted with three bodies, oxides of different radicals, which act the part of bases in the animal fats. These are *glycerin*, the *oxide of cetyl*, and *cerain*: the first of these three is the most widely distributed, and forms the base of the fats of the human body; the oxide of cetyl exists in spermaceti, and cerain in bees' wax. We shall restrict our remarks to glycerin.

*Glycerin*¹ is separated from the fats by the act of saponification, when the acid with which it was combined enters into combination with the new base. The best method of obtaining it in a state of purity is to boil an animal fat with oxide of lead. The salt of lead which is formed is insoluble in water, (it is, in fact, a plaster,) while the glycerin remains in solution. After removing any excess of lead by a current of sulphuretted hydrogen, we must evaporate the fluid *in vacuo* over sulphuric acid.

The glycerin, prepared in this manner, is a clear uncrystallizable fluid, of spec. grav. 1.28, of a yellowish colour, devoid of odour, of a marked sweet taste, very soluble in water and alcohol, but insoluble in ether. It burns with a clear blue flame. It is considered as the hydrate of an oxide of a radical, *glyceryl* (C_6H_7O), which has not yet been isolated. Its composition is expressed by the formula² $C_6H_7O_2 + HO$. Stenhouse assigns the formula C_3H_2O , or $C_3H_2 + O$, and Redtenbacher $C_6H_4O_2 + 4HO$, to this substance. At an elevated temperature, a portion of the glycerin is distilled without change, while the rest is converted into empyreumatic oils, acetic acid, and combustible gases, leaving a carbonaceous residue.

Diagnosis. Glycerin may be recognised by its taste, by its solu-

¹ This substance, glycerin, is united in each fat with a different acid, and hence the fats may be considered as salts of glycerin.

² See Appendix I. Note 23.

bility in water and alcohol, but not in ether, by the absence of crystallization, and by the strong white precipitate which is formed upon the addition of nitrate of mercury.

B. Fatty Acids. We shall now proceed to consider the fatty acids which, in combination with glycerin, constitute the various fats and oils. Two simple fats, *stearin* and *margarin*, and a simple oil, *olein*, with their respective acids, the *stearic*, *margaric*, and *oleic*, are especially deserving of notice.

The researches of Redtenbacher, Varrentrap, and Bromeis, have shown that the two former of these acids are in reality constituents of the same radical, in different stages of oxidation. This radical is termed *margaryl*, and its constitution is expressed by the formula $C_3 H_{3x}$.

In addition to these acids, we find certain fatty acids in butter, which, in combination with glycerin, form distinct fats. Frémy has likewise described a peculiar acid of this nature as existing in the brain, to which he has given the name *cerebric acid*. We omit the consideration of various other fatty acids, which are only met with in particular animals and in the vegetable kingdom.

a. Margaryl and its oxides—stearic and margaric acids. On saponifying mutton fat with potash, dissolving the soap which is thus formed in six parts of hot water, and then adding forty-five parts of cold water, and allowing the solution to rest at a temperature of 60° , we obtain, after some little time, a lamellar precipitate of bistearate of potash, mixed with bimargarate, and a little oleate of the same base. On neutralizing the free potash in the supernatant fluid with an acid, and proceeding as before, we obtain a precipitate of the margarate and stearate of potash. After this process has been repeated several times, nothing but oleate of potash remains in solution. The precipitates must be washed, dried, and dissolved in boiling alcohol. On cooling, the stearate of potash, which is the least soluble, separates first, mixed with a small quantity of the margarate. The more frequently the solution is repeated the more certain are we that ultimately the whole of the margarate will be retained in solution.

The pure stearate of potash is decomposed by warm dilute hydrochloric acid; and the *stearic acid* which precipitates is to be washed in water and dissolved in boiling alcohol, from which it crystallizes, on cooling, in white brilliant scales. By the same process the *margaric acid* is separated from the pure margarate of potash. Margaric acid is obtained most easily from human fat, which contains a very large amount of margarin. Stearic acid melts at 158° . The specific gravity of the acid in its solid state is 1.01. It is perfectly insoluble in water, but dissolves readily in ether as well as in boiling alcohol, in which, on cooling to 122° , crystals begin to form. Its solution exhibits a mild acid reaction towards litmus; in the solid form it burns with a clear flame, like wax.

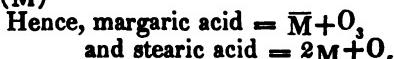
The leading difference between margaric and stearic acids is the greater fusibility of the former, which becomes liquid at 140° . Its

crystals assume an acicular form, and are smaller and less brilliant than those of stearic acid.

Stearic acid is represented by the formula¹ C₁₈ H₃₆ O₂. In its crystalline state it is combined with 2 atoms of water (forming the hydrate of stearic acid), which it gives up on uniting with a base.

Margaric acid is represented by the formula C₁₄ H₂₈ O₂. The hydrate contains only 1 atom of water.

The radical of these two acids, *margaryl*, is represented by the formula C₁₄ H₂₈ (M)

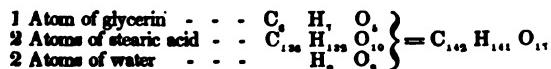


If we treat stearic acid for some time with nitric acid at a temperature of 212°, it becomes completely converted into margaric acid.

A similar, although not so perfect an effect is produced by sulphuric and chromic acids.

The stearic and margaric are very weak acids; at an elevated temperature they have the power of expelling carbonic acid from its combinations; most of the other acids, however, decompose their salts. The alkaline and neutral stearates and margarates are soluble in water; the acid salts (for there are bi- and even quadri-stearates of potash and soda) are not soluble in this fluid, neither are the salts formed with other bases. The stearates of baryta, strontia, and lime are white, insipid, and inodorous powders. The neutral stearates of potash and soda occur in many of the animal fluids, especially in the bile.

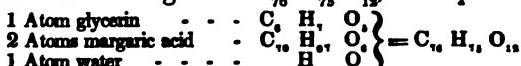
We have already observed that most of the fats are formed by a combination of stearic and margaric acids with glycerin. The *bistearate of glycerin*, or, as it is usually termed, *stearin*, is best obtained from mutton suet, either by washing it with ether as long as any thing is dissolved, or by mixing up melted suet with six times its volume of ether, and subjecting the mass, when cold, to strong pressure. In both these processes the olein, which is fluid at the ordinary temperature, is removed, and the stearin remains behind, although seldom in a state of purity. Stearin melts at 144°. It is insoluble in water, and only dissolves in alcohol with the aid of heat. It dissolves very readily in boiling ether; but, as the ether cools, nearly the whole of the stearin is again precipitated, and at 59° it only retains the one hundred and twenty-fifth part of its weight in solution. It is also soluble in the fatty and volatile oils, and in pyroacetic spirit. The stearin, after being melted down, and allowed to reassume its solid form, appears as a white, semitransparent, uncristalline mass, not unlike wax. Acids and bases convert it into stearic acid and glycerin. The formula for stearin is C₁₄₂ H₂₄₀ O₁₂; it is equivalent to



¹ See Appendix I. Note 24.

The *bimargarate of glycerin*, or *margarin*, is obtained by submitting to spontaneous evaporation the ethereal solution from which the stearin has been separated. The flocculi of margarin that separate themselves must be freed from olein by pressure. Margarin melts at 118°. Its solubility in ether is much greater than that of stearin; at 74° it is perfectly soluble in 5 parts of ether. It is nearly as soluble in alcohol at the ordinary temperature as at the boiling point. In other respects it closely resembles stearin.

The formula for margarin is $C_{76} H_{75} O_{19}$, corresponding with



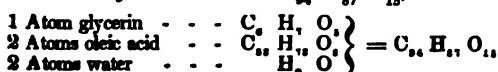
b. Oleic acid. This acid is obtained from the oleate of potash, which is produced during the preparation of the stearate and margarate of potash, and remains in solution. It must be separated by the addition of a mineral acid, and then well washed and shaken in hot water. It is an oily fluid, of a clear yellow colour, and does not assume a solid form until it is cooled several degrees below the freezing point of water. At about 19° or 20° it congeals into white acicular crystals. It is very acid, and has a rancid odour and taste. Its specific gravity is 0.898. It is not soluble in water, but dissolves in alcohol in all proportions, and the spirituous solution acts freely on litmus paper. It combines with stearic and margaric acids in all proportions, and the perfect separation of the acids in such cases is not very easy. Its composition, according to Varrentrap, is represented by the formula $C_{18} H_{32} O_2 + HO$.

Oleic acid may be distilled *in vacuo* without undergoing any change; but if atmospheric air be admitted, a small portion only passes over unaltered, while the greater part is decomposed, and some carbon remains in the retort.



Sebacic acid was formerly considered as a product of the destructive distillation of all fatty bodies, but it has been shown by Redtenbacher to arise only from oleic acid. Oleic acid removes carbonic acid from bases. The oleates do not crystallize; those which are soluble appear as soft, easily fusible bodies, and are more soluble in alcohol than in water. The oleates of potash and soda, if treated with a sufficient quantity of water, become reduced to binoleates, and a portion of the base is freed. The oleate, as well as the stearate of soda, exists in the bile. The *binoleate of glycerin*, usually termed *olein*, exists in small quantity in the various solid fats, but forms the principal mass of the liquid fixed oils. It exists as an oleaginous fluid, and varies in some respects, especially in regard to the point of fusion in the fats of different animals. Chevreul describes the olein of human fat as a colourless oil, devoid of odour, and of a

sweetish taste, which retains its fluid state at 25°. At a lower temperature it assumes a crystalline acicular form. Its specific gravity at 59° is 0.913. One hundred parts of boiling alcohol dissolve 123 of olein; when the solution cools to 170°, it becomes turbid. It is readily soluble in ether, but perfectly insoluble in water. It burns with a clear flame. It dissolves camphor, phosphorus, selenium, the ethereal oils, benzoic and many other organic acids. Its composition is represented by the formula $C_{18} H_{32} O_2$, and is composed of



c. Butyric and its allied acids. Butter contains four volatile acids, which stand in a very simple relation to each other, namely, *butyric acid* = $C_3 H_6 O_2$, *caproic acid* = $C_6 H_{12} O_2$, *caprylic acid* = $C_{10} H_{18} O_2$, and *capric acid* = $C_{18} H_{32} O_2$. Butter sometimes affords, instead of butyric and caproic acids, a distinct acid, *vaccinic acid*, which appears to be equal to the sum of those two acids, minus 1 atom of oxygen, and is very readily decomposed into them. Two of these acids, the caprylic and vaccinic, were discovered only a few months ago, by Lerch, a German chemist. The following is the method that he gives for their separation:

“Fresh butter is completely saponified with potash in a still, the soap decomposed in the vessel with dilute sulphuric acid, the head then luted on, and the aqueous liquid drawn off to within a fourth. Fresh water is then added to it, which is again distilled off, and this operation continued as long as the water which passes over possesses any acid reaction. In this manner the volatile fat acids are carried over just as the essential oils; the action of the atmosphere is moreover entirely excluded. From four to five pints of a milky liquid are obtained from a pound of butter, on the surface of which float drops of oil and particles of hard or smeary fat. The distilled water is immediately saturated in the receiver with barytic water, and allowed to stand well closed till the end of the distillation. When the distillation is finished, the still is cleansed, and the liquid saturated with barytic water, evaporated in it, with the head on, to about the twentieth part, and the still hot concentrated ley then reduced to dryness in a retort.

“The saline mass obtained in this manner consist of two portions, one easy, the other difficult of solution. The more soluble portion consists, according to circumstances, of butyrate and caproate of baryta, or solely of the barytic salt of vaccinic acid; but in this case there is little or no butyric or caproic acid present. The portion difficult of solution consists of the baryta salts of two distinct acids, which Chevreul described together as caprate of baryta. The more insoluble portion amounts to about the twentieth part of the soluble, and the entire mass to about the tenth part of the saponified butter. To separate the different salts, the residuary saline mass is boiled with about 5 or 6 parts of water; one portion dissolves, the other remains

behind. The solution of the readily soluble salts is set aside to crystallize; if, on the first crystallization, the crystals which separate have the appearance of benzoate of lime, and do not effloresce, *i. e.* if they are caproate of baryta, the butyrate of baryta has still to be sought for in the solution; but if nests of small crystals form, which quickly effloresce, and resemble nests of the native carbonate of lime, it is vaccinate of baryta, and it is then unnecessary to look for butyrate and caproate of baryta.

"The circumstances under which butter contains vaccinic acid or butyric and caproic acids are not known. The butter of 1842, and likewise that of the following winter, contained, in several experiments, not a trace of any other easily soluble salt of baryta than the vaccinate: while the butter in the summer of 1843 contained no vaccinic acid, but only the other two.

"The soluble saline mass, containing the butyric and caproic acids is dissolved in water and evaporated to crystallization, in order to separate them. Long silky needles, aggregated in bundles, separate even in the first crystallizations; and if the solution has been sufficiently concentrated, nearly the whole of the caproate salt is deposited. The entire solution solidifies to a paste of minute needles, which are separated by pressure from the mother-ley, and purified by recrystallization. The remaining ley is now allowed to crystallize spontaneously, which is best effected by exposure to the sun; at first a little caproate of baryta still separates, the form of the crystal then changes, laminæ of mother-of-pearl lustre make their appearance, and all the subsequent crystallizations are nearly pure butyrate of baryta, which is purified by recrystallization.

"The saline mass of difficult solution is dissolved in just so much boiling water as is requisite for complete solution, and is filtered while hot. During the cooling, the liquid becomes filled with minute scales of caprate of baryta, of a fatty lustre, which subside in the form of a crystalline precipitate. The decanted mother-ley is again evaporated one fourth, when a fresh quantity of caprate of baryta separates. This salt is purified by recrystallization. The mother-ley now contains the capryllate in solution; it is evaporated by exposure to the sun, when the salt separates in minute granules and verrucous masses, which are obtained pure by recrystallization.

"This is the best method of separating these salts from each other; an absolute separation is impossible, for there always remain mixed crystals and leys, which in small quantities are not worth while working."¹

The butyrate of baryta is much the most soluble of these salts, requiring only 2·77 parts of water. On decomposing it by adding dilute sulphuric acid to its solution we obtain butyric acid, in the form of a colourless or faintly yellow oleaginous fluid.

Butyric acid possesses an unpleasant odour, which calls to mind at the same time that of acetic acid and of rancid butter. It is solu-

¹ Ann. der Chem. und. Pharm. xlix. p. 212, as translated in Number 45 of the Chemical Gazette.

ble in every proportion in water and alcohol, and more soluble in ether than the other acids of the same group. Its specific gravity is 0.963 at 59°; it evaporates easily in the open air, boils under ordinary pressure at about 327°, and distils without undergoing any perceptible alteration. Its vapour is inflammable, and burns with a blue flame. A continued cold of 4° does not produce any change in the state of the butyric acid; its taste is strongly acid and burning; it attacks and disorganizes the skin in the same manner as the strongest acids.

The chemical relations of this acid have been made an object of especial research by Chevreul, Pelouze and Gelis, and Lerch, and numerous butyrates and butyric ether have been formed, and submitted to careful investigation and analysis.

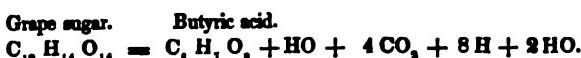
The only compound of butyric acid that concerns us at present is the *butyrate of glycerin*, or *butyrin*, the essential fatty matter of butter. In order to isolate butyrin from the various compounds with which it is associated in butter, we must adopt the following method. Purified butter must be kept for some days at a temperature of about 66°. At that temperature olein and butyrin are liquid, while the solid stearin forms a mass by degrees, so that the liquid portion may be decanted off. On this decanted oily matter its own bulk of absolute alcohol must be poured, the mixture must be left for twenty-four hours, and the temperature be regulated to 66°. On distilling off the alcohol from this alcoholic solution a residue of butyrin is left mixed with a little olein. A slightly acid reaction is usually observed, in consequence of the decomposition of a little of the butyrin into butyric acid. This may be removed by digesting the butyrin in a mixture of magnesia and water. A butyrate of magnesia, soluble in water, is formed, and the butyrin may then be obtained perfectly neutral. The removal of all traces of olein from butyrin is nearly impossible.

Butyrin occurs as a colourless oil, which solidifies at 32°, is soluble in cold alcohol, but not in water, is devoid of odour, and produces no effect on litmus. In a warm atmosphere it speedily decomposes, and yields butyric acid. M M. Pelouze and Gelis have recently shown that by a peculiar process of fermentation butyric acid may be obtained from sugar. They recommend the following as the best process for obtaining the largest possible amount of butyric acid from this source.

"A small quantity of casein is mixed with a solution of sugar, indicating 10° on the saccharometer, and sufficient chalk to saturate the whole of the butyric acid which subsequently forms. This mixture is left at a constant temperature of from 77° to 86°. It soon undergoes very considerable alterations; the fermentation, at first viscous, subsequently lactic, gradually becomes butyric. These decompositions are sometimes successive, sometimes simultaneous, without its being possible to regulate their course. The disengagement of gases becomes more abundant, and analyses show that a period ar-

rives when the free hydrogen amounts to a third of the volume of the carbonic acid. At this period the butyric fermentation is in all its vigour; when at last, at the end of some weeks, all disengagement of hydrogen has ceased, the operation is at an end, and the solution then contains only butyrate of lime."

The composition of butyric acid, its proportion which amounted in several experiments to above the third of the weight of the sugar, the liberation of free hydrogen, and of carbonic acid (independent of that which is disengaged from the chalk,) admit of our supposing that, under the prolonged influence of ferments, sugar is decomposed in the following manner:



This formula is merely intended to exhibit the final result, for several chemical processes¹ precede the formation of butyric acid.

By combining the butyric acid formed in this manner with glycerin, they obtained a fatty matter that seemed in all respects identical with butyrin, as described by Chevreul.

Fibrin yields butyric acid as one of the products of its decomposition: the other products of its putrefaction are albumen, carbonic and acetic acids, and ammonia. It may likewise be obtained by heating this substance with potash at a temperature of from 320° to 356°. A small quantity of a volatile fatty acid forms, which remains in combination with the potash, whilst ammonia and other volatile products are disengaged. This acid has not yet been analyzed, but it seems to possess all the properties of butyric acid. (Wurtz.)

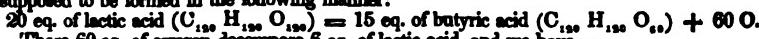
Caproic acid is obtained from the caproate of baryta, which crystallizes in long silky needles, aggregated into bundles.

It is an oily limpid liquid with the odour of sweat, and a sharp acid taste. Its spec. grav. is 0.922 at 72°; it evaporates in the open air; its boiling point is above 212°, and it is soluble in 96 parts of water at 44°. It dissolves in alcohol and ether.

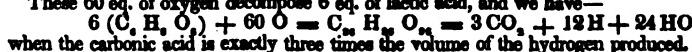
Caprylic acid, at the ordinary temperature, forms a sneaky mass; below 50° it crystallizes in needles, which are of difficult solution in water, have an acid and acrid taste, and a peculiar disagreeable odour. The baryta salt separates from hot solutions in brilliant laminae, but on spontaneous evaporation in white granules. It is anhydrous, is not affected by exposure to the air, does not fuse at 212°, and is very sparingly soluble in water.

Capric acid resembles caprylic acid in its properties. The baryta salt crystallizes from hot solutions in minute fatty needles and

¹ It is well known that if a small quantity of casein be introduced into a solution of cane-sugar or sugar of milk, lactic acid begins very soon to be formed. The butyric acid may be supposed to be formed in the following manner:



These 60 eq. of oxygen decompose 6 eq. of lactic acid, and we have—



scales, and on spontaneous evaporation likewise in scales, arranged in dendritic groups; it is very difficult of solution, is anhydrous, and is not affected by exposure to the air.

Vaccinic acid. Vaccinate of baryta separates in nests of crystals, which have already been described; they contain water of crystallization, effloresce very readily in the air, become very similar in appearance to chalk, and diffuse a strong odour of butter, while pure caproate and butyrate of baryta do not effloresce in the least, and have scarcely any odour. Vaccinate of baryta is soluble in water to about the same extent as butyrate of baryta; the saturated solution is thick like oil. When vaccinate of baryta is dissolved in water, and again evaporated in a retort, it crystallizes from the solution unaltered; but if the crystals are exposed for some time to the air, they at last lose nearly all their odour, and no longer when dissolved crystallize on evaporation, but in their stead crops of caproate and butyrate of baryta are obtained. The same happens when a solution is exposed to the air for any length of time, or boiled in an open dish. No baryta separates in this change, no acid vapours are given off, and the solution remains perfectly neutral. Vaccinic acid therefore saturates exactly the same amount of baryta as the two acids which have originated from it; the relative quantity of the caproate and butyrate of baryta formed is proportionate to the atomic weights of these two salts. If vaccinate of baryta is decomposed by sulphuric acid, with free access of air, and the separated acid removed by distillation, saturated with baryta, and set aside to crystallize, a mixture of caproate and butyrate of baryta only is obtained. On adding some solution of silver to a solution of vaccinate of baryta, a white caseous precipitate is formed, which is soon reduced, and smells strongly of butyric acid.

Vaccinic acid has, therefore, evidently the same capacity of saturation as caproic and butyric acids together, but probably contains less oxygen.

In all probability these acids form compounds with glycerin, and exist in butter as distinct fats.

The brain contains several distinct fats which have been examined by different chemists (Kühn, Couerbe, Frémy,) and found to contain phosphorus and sulphur. Couerbe has given to these the names of *eleencephol*, *cerebrot*, *cephalot*, and *stearaconot*. Cephalot is the only one that is saponifiable, and which, therefore, comes under the category of the true fats. Its fatty acid is unknown; in fact, the whole subject of the brain-fats requires an entire revision.

Frémy¹ has described two fatty acids that exist in the brain in combination with soda, to which he has applied the names of *cerebric* and *oleophosphoric acids*.

Of the bodies just described, those which act the part of bases, never occur naturally in an isolated state; and those which act as acids, very seldom. Butyric acid occasionally exists in a free state

¹ *Annales de Chimie*, 1841.

in the urine, and, according to Gmelin, in the gastric juice, and occasionally in the cutaneous transpiration. Lecanu states that the margaric and oleic acids exist in a free state in the blood. Some of the fatty acids, as already observed, exist in the bile and in the cerebral matter, in combination with soda, but they are most commonly found united with glycerin.

The contents of the cells of ordinary adipose tissue are a mixture of stearin, margarin, and olein; and the marrow of the bones has a very similar composition. The relative proportions of these three substances varies in the fat of different animals, which is the reason of the different consistence of various fats. The more olein present, the softer and more liquid will the fat be: and those fats in which the olein forms the principal ingredient are called oils. Those of a mean consistence are most properly termed *fats*, while the harder ones are known as *suet*. Stearin is the principal constituent of suet; margarin of fat or lard. Human fat affords a good illustration of the proper fats. It solidifies at 62°; but the consistence is not constant, even in the same person—for instance, the fat of the kidneys is perfectly solid at 62°, while the fat of the subcutaneous tissue remains fluid as low as 59°.

The non-saponifiable fats.

a. *Cholesterin* is a normal constituent of the bile, of the brain, and of the spinal cord. It has been found by Lecanu, Denis, Boudet, Marchand and Simon, in the blood; by Fromherz and Guggert in the *vernix caseosa*; by Breschet, Wöhler, and Marchand, in hydrocele; by Stromeyer in an encysted tumour in the abdomen of a woman; by Breschet and Barruel in the ovary and testicle in a diseased state; by Caeventou in an abscess of the tooth; by Lassaigne in a scirrhouss structure in the mesocolon; by Guggert in fungus medullaris, by Marchand in medullary sarcoma, and by Drunty in a vesical calculus extracted from a dog. It sometimes exists in a state of solution, while in other cases it floats on the surface, either in the form of brilliant scales, or of solid masses. It has never been found in any of the plants which are used for food; but Dumas has found a substance of a similar composition in the resin of the pine.

In order to obtain it from biliary calculi, we must first treat these with boiling water, then triturate dry, and pulvérize the residue, treat it with boiling alcohol, filter it while still hot, and allow it to cool very gradually. The cholesterin separates itself in the form of white, sparkling, transparent scales. These should be collected in a filter, again dissolved in hot alcohol, and allowed to recrystallize. In this state it will be tolerably pure. Berzelius recommends the previous addition of a few drops of caustic potash or ammonia, in order to saponify any stearic or margaric acid that may be present.

In order to obtain it from the brain, that organ must first be deprived of all its water, by being finely triturated and then placed upon the water-bath. This being fully accomplished, it must be

treated with ether, and afterwards with boiling alcohol, until these fluids cease to abstract any thing more. As the alcoholic solution cools, a white powder is precipitated. By gently distilling the ethereal solution, a residue remains, from which cholesterin may be taken up by boiling alcohol; on mixing the two alcoholic solutions, evaporating to one fourth, and allowing the mixture to cool, a portion of the fat separates in the form of a white powder, which consists not merely of cholesterin, but also of a substance which is insoluble in cold ether, the *cerebrot* of Couerbe. If, therefore, we treat this fat with ether, the cholesterin dissolves, while the cerebrot remains unacted on. By evaporation we obtain the cholesterin in a crystalline state, and by dissolving it in boiling alcohol and allowing it to recrystallize on cooling, we obtain it in a state of purity.

On slowly cooling its alcoholic solution, cholesterin crystallizes in delicate white nacerous scales. It is devoid of taste and smell, is insoluble in water, but dissolves in alcohol and in ether. According to Chevreul, 100 parts of boiling alcohol of 0·816 dissolve 18 of cholesterin; if alcohol of 0·840 be used, only 11·24 parts are taken up; on cooling, the greater part is deposited. Kühn states that 1 part of cholesterin is soluble in 12·1 of ether at 32°, in 3·7 parts at 59°, and in 2·2 parts of boiling ether. Cholesterin is perfectly neutral, of about the same specific gravity as water, and at 280° melts into a colourless fluid without undergoing any decomposition. Crystallized cholesterin contains about 5·2° of water. It burns with a clear flame, like wax, and one of its most striking characteristics is, that it is not affected by a solution of caustic potash.

Its composition is represented by the formula C₃₇H₅₈O.

b. Serolin. This name was given by Boudet to a fatty matter which he discovered in the blood. It has been more recently found and described by Lecanu and Sanson. In order to exhibit it, blood must be first evaporated to dryness on the water-bath, and the residue treated with water as long as any thing continues to be taken up. It must then be dried, pulverized, treated with boiling alcohol, and filtered while hot. On cooling, the alcohol deposits this fat in flocculi. It must be collected on a filter, and washed with cold alcohol. Boudet assigns the following characteristics to serolin. It forms flocks of a fatty nacerous appearance, is perfectly neutral, and melts at 97°. On exposing it to a higher temperature, a portion is distilled unchanged, while another part is decomposed into ammoniacal vapour. In water it is perfectly insoluble, in hot alcohol of 833 it is only slightly soluble, and separates on cooling into its original flocculent appearance, since cold alcohol exerts no solvent influence over it. It dissolves readily in ether. It does not form a soap with caustic potash. Lecanu describes the serolin obtained from human serum as a white, but not nacerous, substance, which melts at 95°, is soluble in ether, but not in watery alcohol.

It may be distinguished from other fats by its insolubility in cold alcohol; from cholesterin, by its lower point of fusion.

Diagnosis. The different fats and fatty acids are distinguished by their fusing points and by their varying degrees of solubility in alcohol and ether.

Lactic, Oxalic, and Acetic Acids.

1. *Lactic acid* is regarded by most chemists as a constituent of almost all the fluids of the animal body.

The following is the method recommended by Mitscherlich,¹ for the exhibition of pure lactic acid. Sour whey must be evaporated to about one sixth of its volume, and filtered; the phosphoric acid precipitated by lime, and any excess of lime separated by oxalic acid.

After filtration, the liquid must be evaporated to the consistence of a thick syrup, and the lactic acid extracted with alcohol. The alcohol must be removed by evaporation, and the residue dissolved in water mixed with carbonate of lead. In this manner a solution of lactate of lead is obtained, which, after filtration, must be decomposed by sulphate of zinc. Sulphate of lead is immediately precipitated, and lactate of zinc remains in the solution, which must be filtered and evaporated to incipient crystallization. In this manner we obtain crystals of lactate of zinc, a salt only slightly soluble in cold water. Lactic acid may be obtained by converting the lactate of zinc into a lactate of lime or baryta, carefully removing the base by the addition of sulphuric acid, and cautious evaporation.

Pure lactic acid is a colourless liquid, soluble in every proportion in water and alcohol, of a purely acid taste, and so strong and biting as to be almost insupportable. Its formula² is



At a red heat lactates with fixed bases are converted into carbonates: 100 parts of the carbonates of potash and soda correspond to 180·9 and 201·1 parts of the respective lactates of those bases.

There is no ready test by which we can detect the presence of lactic acid: it is chiefly distinguished by its negative properties. Rules for the quantitative determination of this acid and its salts will be found in the chapters on the different fluids in which it occurs; they are founded with various slight modifications on the method that we have given for the exhibition of the acid.

2. *Oxalic acid* is not one of the normal constituents of the animal organism; it is, however, when combined with lime, a very common ingredient of morbid urine, and of urinary calculi.

Oxalate of lime, when obtained by the addition of a soluble oxalate to a salt of lime, occurs as a white amorphous powder, insoluble in water, alcohol, oxalic and acetic acids, but soluble in hydrochloric and nitric acids without effervescence. It leaves, when heated to incipient redness, a white residue of carbonate of lime, from which the amount of oxalate may be easily calculated, for 100 parts of car-

¹ Lehrbuch der Chemie, 1837, p. 512.

² See Appendix I. Note 25.

bonate of lime correspond with 128·9 of oxalate of lime. After a prolonged exposure to a higher temperature, the carbonic acid is expelled, and caustic lime remains.

The occurrence of oxalate of lime in a crystalline state in urinary sediments has been shown by Dr. G. Bird, to be much more frequent than was formerly supposed; in fact, although the beautiful octohedral forms in which it occurs had been noticed some years ago by Vigla, Donné, and other French observers, it was not until the appearance of Dr. G. Bird's papers in the 'London Medical Gazette' for 1842, that their chemical nature was fully established.

3. *Acetic acid* has been found by Tiedemann and Gmelin in the gastric juice, by Thenard in the sweat, by Simon in the fluid of pemphigus and in saliva, and is asserted by some chemists to be a constituent of urine. For its chemical characters we must refer to any of our systematic treatises on Chemistry: it is sufficient to notice the means by which it may be recognised, and its amount determined. Acetic acid may be detected by its peculiar odour, which is rendered more obvious by the application of a gentle warmth. The presence of an acetate may be determined by the addition of a little sulphuric acid; the odour of the liberated acetic acid is at once rendered perceptible. The addition of perchloride of iron to free acetic acid produces hardly any visible change, but if it be added to a solution of an acetate, a deep blood-red colour is produced. When acetates and free acetic acid are mixed up with a large quantity of other animal matters, the best method of proceeding is to separate the free acetic acid by distillation. The residue must be evaporated, extracted several times with alcohol, alcoholic residue mixed with a little sulphuric acid, and distilled. The first distillation gives the free acetic acid, the second the acetic in a state of combination. The amount of acetic acid may be determined by saturating the distilled fluids with potash, evaporating to dryness, and taking up the acetate of potash with alcohol, of ·833. The acetate of potash obtained by the evaporation of the alcoholic solution is frequently mixed with a little chloride of sodium, the amount of which (if appreciable) may be determined by nitrate of silver.

At a red heat the combinations of acetic acid with non-volatile bases are converted into carbonates.

CHEMISTRY OF MAN.

CHAPTER I.

ON THE PROXIMATE ANALYSIS OF COMPOUND ANIMAL SUBSTANCES.

Zoochemical analyses are instituted for the purpose of ascertaining, either quantitatively or qualitatively the proximate or ultimate constituents of animal substances. It is requisite in physiological and pathological chemistry that equal attention should be paid to both these modes of investigation, for there is this great distinction between the chemistry of inorganic and of organic bodies, that in the former case the determination of the proximate principles can be inferred from that of the ultimate constituents, while in the latter case no such rule holds good, and the two species of analyses (the proximate and the ultimate) must be conducted separately and distinctly. In the investigation of the variations in the constitution of the blood, whether dependent during health upon age, sex, or temperament, or during disease upon various pathological states of the system; in the determination of the constituents of milk, sweat, or pus; in the detection of sugar, urea, or bilin, in the various fluids, in which *normally* they are absent; in these and all similar cases ultimate analysis will avail us nothing, and we must have recourse to tests for the substances themselves, or for some of their proximate principles. Investigations of this nature will, moreover, do very little for the advancement of pathological or physiological knowledge, unless they are viewed in relation to a considerable number of similar analyses conducted under precisely corresponding circumstances; for in consequence of the necessary variation that is constantly occurring in the animal fluids, each analysis can only be regarded as the representative of one of innumerable varieties, all of which (within certain limits) are equally likely to occur. It is by such a course alone that we can hope to be able to deduce important and trustworthy conclusions regarding the state of the animal fluids in health, and their various deviations from the normal standard in different states of disease.

A large number of perfectly distinct substances enter into the composition of the blood and urine; neither of these fluids can, however,

be regarded as true chemical combinations, but as mixtures of many such combinations, which in their turn are further subject to much variation. The study of these variations in the blood and urine constitutes one of the most important branches of animal chemistry; but in consequence of the immense labour attendant upon a complete analysis of these fluids, it becomes expedient to confine our attention to their most important constituents, in the same manner as the mineralogist seeks only to determine the proportion of ore in a given quantity of a mineral, or the vegetable analyst to ascertain the proportions of sugar, gum, starch, and albumen, while he neglects the non-nutritive substances, the fibre, acids, resins, colouring matters, &c.

All compound animal substances that can fall within the range of our investigation must be embraced in one of the following classes, the solid, the fluid, or the gaseous.

The animal fluids (to which we shall first devote our attention) differ extremely in their composition, but a general scheme may be laid down for their investigation, if we previously know that certain substances are not present, and therefore need not be sought for. Thus, neither urea, uric acid, pepsin, nor bilin will usually be sought for in the milk or in the brain, because it is well known that their formation is limited to certain organs; neither will haematin, globulin, nor butyryl be looked for in the bile, nor fibrin in the sweat or in the saliva, nor glutin nor chondrin in any of the normal fluids.

The principle upon which these investigations are conducted is dependent on certain questions, which are to be answered by the analysis. Thus in the analysis of the blood, the principal component parts, the water, albumen, haematin, globulin and fibrin, are usually determined; but if it be requisite that the analysis should be more fully carried out, we must separate the haematin from the globulin, isolate the fats, extractive matters, and salts, and determine their individual proportions. This is the plan that I have usually adopted, and in some cases I have added the determination of sugar, urea, and haemaphæin. The execution of such a comparatively simple scheme as this is a matter requiring considerable time and labour; and if it were required that we should carry out the analysis still further, and separate the various fats, the different combinations of the fatty acids, the varieties of extractive matter, and finally the different salts, our task, in the present state of our knowledge, would be one of great difficulty; and in consequence of the minute proportions in which some of these substances exist in the blood, it would be necessary for us to operate upon a much larger quantity of the fluid than we are usually able to obtain. This method of investigation will probably in a short time be deemed insufficient, for as soon as we have an accurate knowledge of the mode of formation of the extractive matter, its separation and determination will be of the highest importance in explaining many of the phenomena of the metamorphoses of the blood.

The same is the case with respect to the urine. The formation of

a perfect quantitative analysis of this complicated fluid is an extremely difficult (if not an impossible) task, in consequence of the facility with which new products are developed during the progress of the investigation. The course usually pursued has been, therefore, the separation of those constituents which are apparently most important, the urea, uric acid, salts, and extractive matter; in some cases the estimation of sugar and albumen has been added. The instances in which the separation of the extractive matter into its three principal groups, and the individual analysis of the salts, have been undertaken, are still more rare.

It has been already observed that a single isolated analysis is of very little intrinsic value, in substances of so varying a nature as the blood or urine. The only method by which we can hope to throw any light upon the leading alterations that occur in these fluids is by the comparison of the results obtained from a series of analyses; and if we were desirous of merely ascertaining so simple a fact as the determination of the pathological states in which either an excess or a deficiency of fibrin and blood-corpuscles occurs in the blood, and the relation that exists between such pathological states and such modifications of the vital fluid, science would be more benefited by the investigation, than by the performance of a few very perfect analyses, which did not tend to elucidate any particular point.

The best methods for the analysis of the various animal substances which are treated of in this volume, will be found in their proper places. We will, however, give a preliminary sketch of the course that should be adopted, if a fluid, of whose nature we are ignorant, be placed in our hands for analysis.

Such a fluid may contain,

- I. The *protein-combinations*; fibrin, albumen, casein, globulin.¹
- II. *Pynn.*²
- III. *Extractive matters*: water-extract, spirit-extract, alcohol-extract, and their proximate constituents.
- IV. *Sugars*: Diabetic sugar, and sugar of milk.
- V. *Bilin*, with the products of its metamorphosis.
- VI. *Urea*.
- VII. The *fats*: olein, stearin, margarin, butyrin, cholesterin, and serolin.
- VIII. *Colouring matters*: the pigments of the blood and bile.
- IX. The acids of the animal body:
 - a. Fatty acids.
 - b. Other organic acids.
 - c. Inorganic acids.
- X. The *bases* of the animal body.

¹ Crystallin, or the modification of casein that occurs in the crystalline lens, is not included in this scheme, since it is not known to occur in any of the animal fluids.

² [Pynn being tritoxide of protein, must now be regarded as a true protein-compound. The binoxide of protein must also be included in the same category.]

General physical analysis.

1. If the fluid contain flocculi or coagulated matters, they are generally composed of fibrin, which by its spontaneous coagulation frequently includes other substances in a state of mechanical suspension. The whole fluid will sometimes assume a gelatinous consistency, as has been observed in certain products of exudation; in other cases it presents an appearance of separation, one portion assuming the form of a cake or clot, whilst the remainder continues fluid, as in the well-known instance of the blood. On placing these clots, &c., in distilled water, the substances which are enclosed by the fibrin gradually separate themselves from it, as for instance albumen, blood-corpuscles, &c., and the fibrin remains devoid of colour, very small in proportion to the clot from which it has been obtained, and forming a membranous, stringy, or flocculent mass.

If the fluid has an acid reaction, the flocculi may arise from coagulated casein, or caseous substances. In this case distilled water has no effect on them. The existence of casein in milk is universally known. Other fluids which contain caseous principles, as, for instance, mucus and saliva, usually maintain an alkaline reaction for a considerable period, and thus hold the casein in solution. Pus has usually a neutral reaction, occasionally however pus from the lungs is acid.

If the flocculi are observed to be floating on the surface of the fluid, if they exhibit a frothy appearance, or seem more or less globular, are of a whitish or yellow colour, and possessed of little tenacity, they are composed of mucus, and the microscope will reveal the presence of mucus-granules. A tenacious substance of a yellow or brownish colour, and not unfrequently containing blood, is occasionally found to be deposited in certain animal fluids, for instance, in the urine during *phthisis vesicæ*. It is possessed of more elasticity than mucus, and is very probably composed partially of fibrin, although it is usually regarded as pus.

2. If with the aid of the microscope we can detect blood-corpuscles in the fluid, we may infer the presence of globulin and haematin. We recognise the blood-corpuscles, and distinguish them from other objects by their discoid form, and their yellow colour. When blood is mixed with a serous or watery fluid, it frequently happens that the discoid form is no longer apparent; if, however, a solution of common salt, or of muriate of ammonia be added to a portion of the fluid, the characteristic shape of the blood-corpuscles will be again rendered perceptible. Fluids in which blood-corpuscles are found, are always of a reddish tinge, and invariably contain albumen.

3. The microscope further enables us to detect the following solid forms in fluids: *a*, fat-vesicles; *b*, chyle-corpuscles; *c*, mucus-corpuscles; *d*, pus-corpuscles; *e*, epithelium-cells; *f*, saliva-corpuscles; *g*, various crystalline forms of salts, uric acid, cholesterolin, &c.

If the fluid be very viscid and tenacious, mucus-corpuscles are sure

to be detected by the microscope: should it yield an ammoniacal odour as if decomposition were going on, the viscosity may be due to the action of the ammonia that has been formed.

4. If the fluid have an acid reaction, a free acid must be present. In most cases this is lactic,¹ occasionally, however, acetic acid. The latter acid may be recognised by the peculiar odour evolved on the application of heat. It may also be recognised (if the fluid be not very deeply coloured) by the blood-red tint that is produced by the addition of the perchloride of iron, after the free acid has been thoroughly neutralized by ammonia. If acetic be the only free acid, by the time the fluid has been evaporated nearly to dryness, all acid reaction will have disappeared; if, however, free lactic acid be present, the residue which is left after evaporation, will still have an acid reaction.

If the fluid have an alkaline reaction, either a free alkali or an alkaline carbonate must be present. Free ammonia may be recognised by its peculiar odour, and by the vapour which is developed on the approximation of a glass rod moistened with hydrochloric acid.

5. If the fluid have a sweetish taste, it contains sugar. The sweetness is, however, sometimes not perceptible until the fluid has been evaporated to the consistence of a syrup, or even till the syrup has been treated with alcohol of .900, and the alcoholic solution evaporated. When the presence of sugar is suspected, the various tests mentioned in page 64, more especially Trommer's test, should be applied. If the fluid has a bitter taste, more or less resembling that of bile, it contains either *bilin* or the products of its metamorphosis. The indications afforded by a well-marked saline or acid taste are sufficiently obvious.

6. If the fluid be of a blood-red colour, we may conclude that hæmatin is present; and if blood-corpuscles are detected by the microscope, we have certain proof of the existence of hæmatin, globulin, and albumen. Globulin and hæmatin may, however, be occasionally present, when, even after the addition of a solution of salt, sugar, or iodine, no blood-corpuscles can be detected; in this case the latter are in a state of perfect solution.

When the fluid is of a dark brown, or blackish-red colour, hæmatin is the colouring constituent. If the fluid be of a clear brown or yellow colour, hæmaphæin is almost sure to be the origin of the tint, especially if any taste of bile be perceptible. Biliphæin will also communicate a yellow, brown, or greenish-brown colour; in this case there is frequently a bitter taste, and on the addition of nitric acid, there is always a change of colour into green or blue, and yellow.

¹ [The presence of this acid in the animal fluids has been recently disputed by Liebig and Enderling; there are, however, too many chemists who assert that they have detected it, to allow us to regard the question as settled in the negative.]

Qualitative analysis.

Having poured the fluid into proper test-glasses, we carry on our investigations in the following manner:

1. If, on the addition of very dilute hydrochloric acid, a precipitate be thrown down, we see whether it will dissolve in an excess of the test.¹ Assuming that the solution is effected, ferrocyanide of potassium is added; if this test instantly throws down a white or yellow precipitate, one or more of the protein-compounds (enumerated in 1) are present.

In order to ascertain which of the protein-compounds has yielded these indications,² a portion of the fluid is boiled: if it become turbid, and if the turbidity commence and be most distinct at the surface, or if the fluid coagulate, then albumen is present; in this case nitric acid and bichloride of mercury will throw down copious precipitates. If the fluid become turbid on the application of heat, and the coagulum assume a red tint, then globulin and haematin are also present, although the microscope may have failed in detecting blood-corpuscles: in this case, however, the fluid is always of a rather pink or reddish tint.

If the fluid does not coagulate on the application of heat, casein, or one of the caseous substances must be present. In this case heat will develop a pellicle on the surface, and acetic acid will throw down a precipitate, which is soluble in an excess of the test: the acid must therefore be added with caution.

It must not, however, be forgotten, that if much albuminate of soda, and at the same time no free albumen be present in the fluid, no coagulation will occur on the application of heat, but a pellicle will be formed on the surface. This is, however, a case of very rare occurrence, and the difficulty may be readily solved by the addition of acetic acid which will precipitate casein but not albumen. If a fluid which contains casein presents a whitish turbid appearance (as for instance, milk, the milky fluid which is found in the breasts during the later stages of pregnancy, the urine in certain pathological states, &c.) the presence of butter, and in most instances, of sugar, may be inferred.

If the ferrocyanide of potassium does not produce any turbidity in the fluid which has been previously acidulated with dilute hydrochloric acid, *no protein-compound is present.*

2. If the addition of acetic acid to the fluid renders it turbid, or throws down a precipitate, which does not redissolve in an excess of the test, then pyin or mucin³ is present. In this case, a copious pre-

¹ If very dilute hydrochloric acid be employed, the albumen will not be precipitated. (See p. 18.) I prefer hydrochloric to acetic acid, because the latter throws down pyin with the protein-compounds.

² Fibrin is recognised by its spontaneous separation, and need not be sought for in the manner indicated in the text.

³ [Mucin is the peculiar animal matter of mucus; a brief notion of its leading characters is given in the chapter on the "Secretions of Mucous Membranes."]

cipitate, insoluble in an excess of the test, is thrown down by alum. In order to show that the precipitate contains no casein, we may dissolve it in dilute hydrochloric acid, and add ferrocyanide of potassium: no precipitate will be thrown down.¹

3. If allantoin, uric acid, or hippuric acid are suspected to be present, a considerable quantity of the fluid must be boiled in order to coagulate any albumen that may be present, and must then be filtered and evaporated to one fourth of its original volume. Fluids of this nature are generally of a yellowish colour, may be either clear or turbid, and may or may not contain albumen.

In the examination of the allantoic fluid, crystals of allantoin are gradually formed, which, after being purified by recrystallization, and dissolved in water, cannot be precipitated by acetate of lead, nitrate of silver, or nitrate of the black oxide of mercury.

If the fluid, during evaporation, gives off a urinous odour, some hydrochloric acid must be added, and it must be allowed to stand for some time. If acicular crystals are formed, which, after being purified by recrystallization, and dissolved in water containing enough alkali to neutralize the acid of the crystals, give a white precipitate with the above-named tests, an orange with the perchloride of iron, and when moistened with nitric acid, and warmed, do not assume a purple-red colour, they consist of *hippuric acid*.

If, however, the crystals are very minute, are not readily dissolved in water, and give, when moistened with nitric acid and warmed, a purple-red stain, they are *uric acid* crystals.

4. If the fluid which we are examining is of a brownish-yellow colour, and if on treating a little of it with an excess of nitric acid, the colour successively changes to green, blue and red, then biliphaein is present.

5. On evaporating a portion of the fluid to dryness, pulverizing it, and boiling it with ether, we obtain, by the evaporation of the ethereal solution, a fatty residue. If it be fluid, it is composed of olein, if it have a tendency to be solid, either stearin or margarin, or both are also present. The fatty acids, and probably free lactic acid, with traces of other substances may be present, especially if the ether contained any alcohol or water. These substances remain in solution, on washing the fatty residue with water. The lactic acid may be easily recognised by its acid reaction; and the fatty acids may be detected by the addition of acetate of lead or acetate of copper to their alcoholic solutions. They are completely precipitated in this manner, and a residue of pure fat is left, which must be again washed, and the water removed by evaporation. The fat must then be saponified; if a portion of it resists this process, cholesterin or serolin, or both, must constitute a portion of the fatty residue. They must be taken up by ether, after the saponified portion has been evaporated to dryness. Serolin is less soluble in alcohol, and melts at a lower temperature.

¹ As chondrin and glutin are not constituents of any of the animal fluids, we have deemed it unnecessary to notice them in the text.

rature than cholesterin,¹ by which means the two fats may be distinguished. The soaps which have been formed must be decomposed by hydrochloric acid. If, on the addition of the acid, a smell of rancid butter is developed, then butyric, and also capric and caproic acids are present. The variations in their melting points will enable us to determine approximately the proportions of oleic, margaric, and stearic acids.

6. The residue not taken up by ether, must be treated with anhydrous alcohol, which will take up the following substances: salts of the fatty acids, especially soda-salts, as well as any fat that had escaped the action of the ether, also urea, bilin, and the acids of the bile, biliverdin, alcohol-extract, haemaphæin, acetates, and lactates, a class of substances which it is by no means easy to distinguish, and is still more difficult to isolate. If a spirituous solution of chloride of barium be added to the alcoholic solution, and a green precipitate is thrown down, then biliverdin is present; we may also calculate with tolerable certainty (especially if the alcoholic solution has a bitter, biliary taste) on the presence of bilin, and the acids of the bile. An alcoholic solution of sulphuric acid must now be added to the alcohol-solution that we are testing, as long as any sulphates are precipitated. The solution must now be filtered, and the alcohol, which still has an acid reaction if any acetates are present, must be removed by distillation. On treating the residue with water, the fatty acids, if they existed in combination with saline bases, will remain undissolved, and must be removed by filtration. A portion of this watery solution must be evaporated to the consistence of a syrup, and allowed to cool; if, on the addition of an excess of nitric acid, there are formed, either at once or after some time, leafy or stellar crystalline groups, then urea is present. Another portion must be treated with dilute sulphuric acid, and allowed to digest for some time. If bilin, and the products of its metamorphosis, are present, a viscid or oily acid, (insoluble in the acid fluid,) and a precipitate of an extremely unpleasant bitter taste, are formed. The fluid separated from these substances must be digested with pounded marble, or (which is better) with carbonate of baryta, in order to remove the sulphuric acid. It must then be boiled with carbonate of zinc; if it contain lactic acid, crystals of lactate of zinc will be obtained by evaporation. The extractive matter and haemaphæin will be left as a residue.

If neither bilin, biliverdin, nor the acids of the bile are present, the investigation may be much simplified. The soda may be separated from the alcoholic solution as a sulphate; we may evaporate, separate the fatty acids by means of water, boil the residue with carbonate of zinc, and filter the solution. By this means we can separate the lactic acid. The urea may be separated from the alcohol-extract by oxalic acid, of which any excess may be removed by digestion with carbonate of lead.

We may be easily convinced of the presence of the alcohol-extract

¹ [Serolin melts at 95°, cholesterin at about 275°.]

by observing the precipitates which are thrown down by the addition of infusion of galls and a solution of iodine.

The bases which were present in the alcoholic solution in combination with acids, are now combined with sulphuric acid. They usually are soda and potash.

7. The residue of (6,) which was not taken up by absolute alcohol, must now be treated with alcohol of .833, which will take up sugar of milk, diabetic sugar, spirit-extract (which is usually of a brown colour in consequence of the presence of hæmaphæin,) chloride of sodium, phosphates, and probably lactates. If the quantity of sugar (of either of the above kinds) is not very minute, a portion of it will usually crystallize either on the cooling of the spirituous solution or by spontaneous evaporation. The presence of the sugar may, however, be easily recognised by the sweet taste of the spirituous solution after evaporation. If the solution be evaporated to the consistence of an extract, and then treated with cold alcohol of .850, the greater part of the sugar will remain undissolved, while most of the extractive matter will be taken up. The presence of the extractive matter may be determined partly by the brown colour of the spirituous solution, and more decidedly by the precipitates which are caused by the addition of bichloride of mercury, acetate of copper, and tannin. The spirit-extract usually evolves during evaporation a peculiar odour, somewhat resembling that of toasted bread. On evaporating a portion of the spirituous solution to dryness, and incinerating the residue, the ash will be found to consist of chloride of sodium, phosphates, and (if any lactates are present) carbonates of potash and soda. These may be separated in the ordinary manner.

8. The residue not acted on by alcohol of .850 must be dissolved in water, in which, if no protein-compounds are present, it will dissolve without leaving a residue, although the solution may not be clear. In this solution there will be contained pyin, ptyalin, water-extract, phosphates, and perhaps some chloride of sodium. The pyin is recognised by the precipitate afforded by acetic acid. The ptyalin, when it is present only in small quantities, and is mixed with extractive matter, is not easily detected; the only course we can adopt is to precipitate the whole of the extractive matter of the water-extract with the basic acetate of lead. A stream of sulphuretted hydrogen must then be passed through the fluid in order to precipitate the lead. The liquid, after filtration or decantation, must be evaporated to the consistence of a syrup, and the ptyalin precipitated by alcohol.

I may here remark that, in pursuing the directions laid down in (7,) we do not succeed in obtaining all the spirit-extract that exists in the residue of (6.) Hence in practice it is better to dissolve the residue of (6) in a little water, so as to reduce it to the consistence of a syrup, and then to precipitate with alcohol of .833. The salts may be obtained by incinerating a portion of the evaporated fluid.

In the last six paragraphs we have assumed that no protein-compounds are present. If, however, this should not be the case,—if

some of the constituents of the blood, as, for instance, globulin or hæmatin, exist in the fluid, a different course must be pursued. The presence of globulin and hæmatin, and, consequently, of albumen, may be easily ascertained. The fluid must be boiled, evaporated on the water-bath to dryness, and the residue reduced to a fine powder. The fat must be taken up with ether, and the urea, alcohol-extract, bilin, with its acids, and any hæmaphæin and lactates that may be present, with anhydrous alcohol. The residue must be boiled in spirit of .915 until it ceases to communicate any additional red colouring matter to that fluid. In this way we shall obtain the globulin, hæmatin, hæmaphæin, sugar, extractive matters, and several salts, in a state of solution. The greater portion of the globulin and hæmatin is thrown down as the fluid cools; the turbid supernatant fluid is then evaporated on the water-bath to a small residue, and treated with alcohol, which precipitates the remaining portion of those two constituents. Other substances are contained in the spirituous solution, which may be distinguished and separated by the rules already given.

The residue not taken up by the alcohol of .915 must be treated for some time with water, by which pyin, ptyalin, and water-extract will be taken up. The albumen remains as a residue, usually more or less reddened by a little hæmatin.

If the fluid be very rich in albumen, this course does not succeed, inasmuch as we are unable to obtain a complete separation of those substances which are soluble in dilute alcohol, as sugar, urea, salts, and extractive matters. The following simple modification may in that case be adopted. The protein-compounds must be precipitated by anhydrous alcohol. A spirituous solution is thus obtained, which, even when concentrated, holds the urea, sugar, &c., in solution, while the protein-compounds (at least the albumen) are reduced to an insoluble condition. The coagulated protein-compounds are always mixed up with a certain amount of foreign matters, as, for instance, water-extract, which cannot be easily separated. After the removal of the albumen, &c., the spirituous solution must be evaporated to the consistence of a syrup. On the addition of anhydrous alcohol, sugar, spirit-extract, any albumen that had escaped the former process, and some other substances, will be precipitated. The alcoholic solution must be evaporated, and the residue dissolved in water, by which means the fat will separate itself. The fat is, however, difficult to remove, in consequence of the slow and torpid manner in which the fluid permeates the filter. It is better, therefore, to evaporate the alcoholic solution, at a very gentle temperature, to dryness, and then to take up the fat with pure ether.

In searching for minute quantities of urea in alcoholic solutions of concentrated animal fluids, it frequently happens that, after evaporation of the alcohol, the removal of the fat, and the solution of the residue in water, the action of nitric acid on the urea is much impeded by the presence of compounds of the fatty acids. I therefore

usually remove the bases from the alcoholic solution by means of sulphuric acid, which liberates the fatty acids, and allows of their removal with the fat by means of ether. The sulphuric acid should be much diluted with strong alcohol; and as it is of importance that there be no excess of the acid, it must be added *guttatim*, and only so long as it produces a precipitate, which sometimes is not observed for several hours after the addition of the acid. The effect of the sulphuric acid should first be tried on a small portion of the fluid.

If it is difficult to lay down general rules for the qualitative analysis of all the proximate constituents that can by any possibility occur in the fluids of the animal body it may easily be conceived that an attempt to lay down similar rules for quantitative analysis would involve much greater difficulties. Such a general quantitative scheme is, however, not required, since quantitative analyses are always preceded by, and based on, qualitative investigations. The fluids most troublesome to analyze are the blood and the urine on account of the large number of different substances that always occur in them. The rules for the quantitative analysis of the various fluids will be found in the respective chapters on the blood, milk, urine, &c.

CHAPTER II.

THE CIRCULATING FLUIDS.

The Blood.

THE following scheme will explain the arrangement which we have adopted for the general consideration of the blood.

1. The General Physiological Chemistry of the Blood.

Its general physiological and chemical relations; the development of the blood-corpuscles; the phenomena of circulation and respiration; the metamorphosis of the blood, and animal heat.

2. The Special Chemistry of the Blood.

The method of analyzing the blood.

Healthy blood.

Diseased blood.

1. The general physiological chemistry of the blood.

General physical relations of the blood.

The blood, while moving in the living body, consists principally of a nearly colourless fluid, in which the blood-corpuscles are swim-

ming; in consequence, however, of these corpuscles being too minute to be distinguished by the naked eye, it appears, among the higher classes of animals, as an opake and intensely red fluid.

In the majority of the lower (invertebrate) animals, the blood is white; it is however red in the annelida, colourless in most of the mollusca, but in many of the snails of a milk-white colour; in the *Helix pomatia* of a sky-blue, and in the *Planorbis corneus*, of a dark amethyst colour. In the dorsal vessels of insects it is usually transparent, and of different colours; it is, for instance, green in the Orthoptera, yellow in the silkworm, orange in the caterpillar of the willow-moth, and of a dark brown colour in most of the beetles.¹ The blood-corpuscles of red blood contain within their coat, or shell, a fluid impregnated with globulin and haematin, and a nucleus, which may be easily recognised in the larger corpuscles.

The blood of the mammalia is a somewhat thick, viscid fluid, with a specific gravity which varies, according to different authors, from 1041 to 1082. In a large number of experiments made upon the blood of man, the ox, and the horse, I found it to be between 1051 and 1058. The average was 1042, which corresponds very nearly with the statement of Berzelius.

[The average specific gravity of human blood may be fixed at 1055 according to Nasse,² and at 1056 according to Zimmermann.³ The blood of man is always thicker, and at least one thousandth heavier than that of woman; in a state of health it is always above 1053 in man, while in woman it is frequently not above 1050. Robust men will not unfrequently yield blood of spec. grav. 1058 or even 1059, while in pregnant women the specific gravity is sometimes as low as 1045. In very young infants the blood is thin, and of low specific gravity; according to Denis the blood of the umbilical arteries has a specific gravity of 1075. The specific gravity of the blood of numerous animals has been determined by Dr. J. Davy⁴ and by Nasse.]

► I found that the blood, as it issues from the aorta, has a temperature of 103° in the ox, and 99°.5 in the pig. Thackray places the temperature of the blood of the horse at 96°.8, of the ox at 99°.5, of the sheep at 101°.3, and of the duck at 105°.8. The temperature is always higher in birds than in the mammalia. The observations of J. Davy, Becquerel, Breschet, Mayer, and Saissy, tend to show that the temperature of arterial is about 1°.8 higher than that of venous blood.

Microscopic analysis of the blood.

If the blood be examined with the microscope (either in a transparent living part, or immediately after its removal from the body,

¹ Burdach's Physiologie.

² Article 'Blut,' in Wagner's Handwörterbuch, vol. 1, p. 82.

³ Hufeland's Journal, 1843.

⁴ Anatomical and Physiological Researches, p. 24.

it will be seen to consist of a great number of yellow corpuscles) swimming in a colourless fluid. In the higher animals the form of these corpuscles is either circular or elliptic, and invariably flattened.

Under a magnifying power of 300 diameters, they assume the appearance of fig. 1a in the blood of man and the mammalia, of fig. 1b in the blood of birds, and of fig. 1c in the blood of fishes and amphibia. Müller¹ found the greatest degree of flattening in reptiles, amphibia, and fishes. He found that in frogs the thickness does not measure more than one eighth to one tenth of the long diameter, and that in man it measures about one fourth or one fifth of the transverse diameter.

In addition to the blood-corpuscles, lymph-, chyle-, and sometimes oil-globules are present. The first two are round, of a finely granular appearance, and about the size of the blood-corpuscles, from which they may be distinguished by their want of colour, their more perfect sphericity, and their granular appearance.

These distinctions are sufficient to prevent them from being mistaken for blood-globules. Globules of oil may be immediately recognised by their well-defined dark edge, and by their great refractive power. They do not rotate, and are not granular, but perfectly transparent.

The size of the blood-corpuscles varies in different animals.

In man, the diameter varies, according to Wagner,² from .0004 to .0002 of a French inch; according to Müller,³ from .00035 to .00023, and according to Schultz,⁴ from .00036 to .00031. The thickness, according to the last observer, may be estimated at .000085 of the same measure. Of all the mammalia, the ruminants seem to possess the smallest blood-globules. Wagner has given the following proportions:

In man and monkeys $\frac{1}{333}$ of a line = 3.

Carnivora. : $\frac{1}{333}$ of a line = 4.

Ruminantia : $\frac{1}{333}$ of a line = 5.

In addition to these admeasurements, the following are deserving of notice: Nasse fixed their average diameter at .00033, the maxima and minima being .00036 and .0003; Bowerbank places their average diameter at from .00035 to .00027, the extreme limits being .00054 and .00021 respectively; Owen at .00028; and Gulliver at .0003 of an inch.

The dimensions of the blood-corpuscles in the following animals have been measured:

Ape (*Simia callitrix*) .00037^s (Prevost and Dumas.)

Cat .00028; dog .00031 (Schultz;) rat and mouse about .00025 (Wagner.)

¹ *Handbuch der Physiologie des Menschen*, vol. 1, p. 105.

² *Nachträge zur Physiologie des Blutes*, 1838, p. 5.

³ *Physiologie des Menschen*, vol. 1, p. 106.

⁴ *System der Cirkulation*, p. 14.

^s French inches.

Sheep ·0002 (Schultz and Wagner;) ox ·0002 (Schultz) and ·00024 (Wagner;) goat ·00017; chamois ·0002 (Prevost and Dumas;) horse ·00031—·00027 (Schultz.) According to Wagner, the diameter in rats, mice, hares, and squirrels, varies from ·00025 to ·00020.

The blood-corpuses of birds, fishes, and amphibia are elliptical.

The following are the results of some of the best authenticated measurements:

Common fowl: length ·00062; breadth ·00036; thickness ·00013 (Schultz) According to Dumas and Prevost, the long diameter in the pigeon, duck, and goose, varies from ·0008 to ·00044; the short diameter from ·0004 to ·00029. Wagner estimates the two diameters, in the pigeon, at ·0008 and ·00033 respectively.

We find the largest blood-corpuses in fishes. According to Wagner¹ the largest corpuses, at present observed, are those of the torpedo, their long diameter being ·002; in the skate he found them to vary from ·001 to ·0012 in length; in the loach the long diameter was ·0005; in the eel-pout, ·00057; in the barbel ·00066, the short diameter in this case being ·0004.

In the carp the long diameter is ·0005, and the nucleus measures ·00012.

In the plaice, Schultz estimated the long and short diameters at ·00062, and ·00043 respectively, and the thickness at ·00007.

In the naked amphibia the corpuses are very large. In the triton, Dumas and Prevost estimated the diameters at ·00128 and ·00078 respectively. In the Salamandra cristata, Schultz found that the diameters were ·00138 and ·000804 and that the thickness was ·000315. In the frog, the same observer estimated the length, breadth, and thickness at ·00108, and ·00058, and ·000017.

Of all the amphibia, the water-snakes appear to possess the smallest blood-corpuses.²

The instantaneous effect of water upon the blood-corpuses is very remarkable, and is easily seen under the microscope; they swell, become globular, lose their distinct contour, and (if much water be added,) altogether disappear. If however the blood-corpuses have nuclei of sufficient magnitude to admit of examination (as in the blood of fishes, reptiles, &c.,) these nuclei will be seen swimming in the water after the disappearance of the capsules.

The nuclei may be separated in a similar manner, by the addition of a little acetic acid. The acid in a few minutes dissolves the haemato-globulin, and assumes a yellow colour.

If, upon the addition of water, the blood-corpuses have swelled to such a degree as to be imperceptible under the microscope, they may be restored to their pristine form by the addition of a solution

¹ Zur vergleichenden Physiologie des Blutes, 1833, p. 14. [The largest blood-corpuses do not occur in fishes, as stated in the text, but in some of the naked amphibia. See Wagner's Physiology, p. 236, English edition.]

² A very complete account of the sizes of the blood-corpuses of different animals, as far as they had been then ascertained, may be found in Wagner's Nachträge zur Physiologie des Blutes, 1839, p. 31.

of sugar, of common salt, of nitrate of potash, or of muriate of ammonia. Schultz¹ explains this phenomenon by the supposition that the capsule of the blood-corpuscle is an organic structure, which is stimulated to contraction by the above solutions, but which is relaxed or expanded by water. In confirmation of this view, he observes that the hæmato-globulin is not precipitated by the action of the sugar or salts. Schultz has also shown that when the capsules have even fallen to pieces in the water, the addition of a little tincture of iodine, diluted with water, will render their fragments visible.

The blood-corpuscles do not always present a regular nummular and flattened appearance; they are sometimes plicated and bent in.

The cause of this phenomenon is not known, but it is probably due to a contraction of the capsule at different points. One of the most peculiar of these forms is that in which the edge of the blood-corpuscle appears as if it were studded with minute pearls. In the blood of a patient suffering from Bright's disease, I found that nearly all the corpuscles had undergone this modification. On the addition of a solution of muriate of ammonia, the appearance it presented under the microscope was very striking. I immediately made a counter-experiment with my own blood, but it did not exhibit the phenomenon in question.

Ascherson² has offered the following explanation of this peculiarity in the form of the corpuscle, viz., that it is due to the exudation of fat which exists in a fluid state in the blood-corpuscle.

In opposition to this view, it may be urged, that if each individual corpuscle contained a separable portion of fat (however minute it might be,) we should obtain in our analyses a much larger quantity of fat than in reality we do. It is true that the dried clot yields a larger proportion of fat than an equal weight of serum, but the difference is by no means so striking as it would have been if Ascherson's theory were correct.

Hünefeld³ has observed a similar appearance on treating the blood-corpuscles of the frog with putrid serum, in which granules were present. The granules seemed to form a sort of girdle round the corpuscle, and he conceives that they penetrated into minute depressions upon the surface of the capsule. If this statement be correct, it is strongly opposed to the observations of Ascherson and Wagner respecting the lubricity and evenness of the blood-corpuscles.

On mixing the blood of a carp with a solution of sugar, and on the cautious addition of water, I observed that the blood-corpuscles assumed a stellar appearance.

On treating frog's blood with bilin, an agent which usually dissolves the corpuscles, I observed that some of them resisted this action for a considerable period, and ultimately assumed a pyriform

¹ Ueber die gebemmte und gesteigerte Auflösung der verbrauchten Blutbläschen. Hufeland's Journal, April, 1838, p. 18.

² Müller's Archiv. 1840. Ueber die Bedeutung der Fettstoffe.

³ Der Chemismus in der thierischen Organisation, p. 101.

appearance, while others became narrowed at the centre, and extended at both extremities. Others, again, seemed to undergo an internal change, and appeared as if their inner surface were studded with minute vesicles.

Hünefeld made a similar observation on treating frog's blood with carbonate of ammonia.¹

The same chemist observed a remarkable peculiarity in the corpuscles of human blood, on the addition of sulphate of quinine. In the course of a few minutes they assumed an irregular, angular form, and appeared as if their sides were drawn together.

Schultz² has made the following important microscopic observation. On examining the blood-corpuscles of a salamander which had been suffocated in carbonic acid gas, they were found to be of a darker colour than usual; the darkness was particularly marked on some spots, so that they exhibited a sort of chequered appearance.

On shaking the blood with oxygen gas, the corpuscles became brighter and more transparent.

A. The general chemical relations of the blood.

The general chemical relations of the blood-corpuscles.

Müller and Schultz have examined the action of various tests on the blood-corpuscles. Hünefeld³ has also recently paid much attention to the apparent effect produced on them by numerous medicinal agents. According to the last-named author, the corpuscles and their nuclei are soluble in the following substances: caustic ammonia, potash, soda, lime, and baryta, soap, bile, acetic acid, hydrocyanic acid, alcohol, ether, oil of turpentine, ethereal oil, and sulphuret of carbon.

The capsules, but not the nuclei, are soluble in water, in all the salts of ammonia, the carbonates of potash and soda, cyanate of potash, borax, chloride of barium, chloride of calcium, the salts of oxalic and hydrochloric acids, concentrated vinegar, and the phosphoric, arsenic, oxalic, citric, and hydrochloric acids.

Phosphorus, chlorine, and iodine produce a similar effect, probably by the formation of an acid.

An imperfect solution is effected by flowers of sulphur, tartrate of ammonia, borate of ammonia, bromide of potassium, and malic acid.

The corpuscles are not dissolved by carbonate of magnesia, veratrine, strychnine, acetate of morphine, hydrochlorate of cocaine, boracic acid, carbonic acid, nitrate of potash, nitrate of soda, tartrate of soda, phosphate of soda, chloride of sodium, sugar, gum, sulphate of potash, sulphate of magnesia, sulphate of soda, tartar emetic, camphor, anemonine.

Hünefeld also tried the effects of several of the animal fluids on the blood. Saliva, phthisical sputa, and healthy pus produced no

¹ L. c., p. 106.

² Der Chemismus, u. s. w., p. 43-84.

³ System der Cirkulation, p. 27.

well-marked changes. Gastric juice, added to an excess of blood, induced a slight coagulation, and changed the red colour into a brown. The extractive matter of the flesh of rabbits and calves produced no change on the corpuscles, but the colour assumed a more vermillion tint, and the corpuscles sank sooner than usual. Acid whey, concentrated by evaporation, produced no effect, neither did the pancreatic juice or gonorrhœal discharge. Sweat, taken from the axilla, changed the colour to a lighter red, and, in the course of some hours, dissolved the corpuscles, (possibly through the influence of the ammoniacal salts.)

Pure urea, prepared artificially, induced no change in the colour, but dissolved the corpuscles, with the exception of the nuclei and a few fragments of the capsules.

The action of putrid blood and serum has been already noticed.

Human blood does not appear to be influenced by admixture with the blood of birds or frogs.

The bile of man, quadrupeds, birds, fishes, and amphibia, exerts an active soluble influence upon the corpuscles. In some observations on frog's blood, Hünefeld noticed that the capsules were immediately dissolved, and that the nuclei remained unchanged for some time, but ultimately broke up into minute granules and disappeared.

The effects produced by coneia appear, from Hünefeld's observation, to be very singular.

Coneine, either in a state of solution or vapour, reduces the blood to a dirty red greasy mass, which, under the microscope, resembles dark melted wax, and in which no corpuscles can be detected. If diluted blood be treated with a little coneine, it remains fluid, but, after a short time, becomes discoloured, and throws down a brown sediment. The blood of a rabbit, poisoned with coneine, exhibited no peculiarity.

Arsenic acid produces no material effect upon the blood, nor could Hünefeld detect any alteration in the corpuscles of a frog destroyed by this agent.

On passing hydrocyanic acid, in a state of vapour, into the blood of a pig, the colour became more vivid, and the corpuscles remained uninjured for a very considerable time. A large quantity of blood, which was treated in a similar manner, gave off a strong odour of the acid after the lapse of a year and a half, and did not exhibit any symptoms of putrefaction. No change could be observed in the blood of a rabbit poisoned with this agent.

Chlorate of potash does not produce any apparent effect for the first few minutes; subsequently, however, the blood assumes a brighter red tint, which ultimately passes into a brown. An ounce of fresh human blood was mixed with eight grains of chlorate of potash. Just at first the colour became rather brighter, but, after the lapse of from fifteen minutes to an hour, it became darker than it previously was. It then became of a reddish brown colour, and

after from eight to sixteen hours, it was converted into a pulpy brownish-black matter. The blood of a cat which had taken a drachm of this salt, and had afterwards been killed with cyanogen, exhibited no peculiar appearance.

Hünefeld, and some other microscopists, assert that acetic acid dissolves the whole of the corpuscle, with the exception of the nucleus. Müller, on the contrary, maintains that in frog's blood the colouring envelope is not wholly dissolved, but may still be frequently observed in a pale fine line surrounding the nucleus.

The following are my own observations with respect to this test. If a sufficient quantity of acetic acid be added to freshly drawn blood, so as to give it a decidedly acid reaction, and if the vessel in which it is contained be submitted to a temperature of about 88° for half an hour, the blood becomes changed into a thick tar-like mass of a blackish brown colour.

If water be now added, and the mixture carefully stirred until it is reduced to a magma of an equal consistence throughout, we find that, on examining a portion of this mixture under the microscope, the addition of some more water does not dissolve the corpuscles; in fact, they are no longer soluble in water, in consequence of the insoluble compound that has been formed by the acetic acid, and the (casein-like) globulin. If a great excess of water be added, the corpuscles sink; the albumen, and a great portion of the haematin, which enter into their composition, are dissolved, and they become almost perfectly clear. They may even be boiled in water, without any change in their form being produced.

When boiled in acetic acid (unless it be very dilute,) they become perfectly dissolved, with the exception of their nuclei.¹

According to Müller and Schultz, a solution of caustic ammonia dissolves the corpuscles more rapidly than a similar solution of caustic potash. The same observers state that alcohol does not dissolve them, but merely produces a slight contraction or puckering, and that the granules of albumen coagulated by this reagent, cloud the field of vision, and render the corpuscles indistinct. I have also found that neither absolute alcohol, nor alcohol of $\cdot 835$, effect the solution of the corpuscles.

It has been found by Schultz, Hünefeld and myself, that the blood-corpuscles dissolve upon the addition of a small quantity of ether. A quantity corresponding in volume to from one third to one half of the blood is perfectly sufficient. This experiment has been successfully repeated upon the blood of man, the ox, the frog, and the carp.

If the experiment be performed in a test-glass, it will be observed that the colour of the blood very soon becomes deepened, but that ultimately the whole fluid becomes transparent. The ether does not separate during this process.

If a portion of this mixture be covered with a slip of thin glass,

¹ F. Simon's Beiträge zur Kenntniß des Blutes, in Brandes's Archiv. vol. 18, p. 35.

and examined under the microscope, no corpuscles, but simply the nuclei, are discernible. The nuclei in the blood of man and the ox cannot be clearly seen on account of the colouring matter that is always present; they may, however, be always distinctly observed in the blood of the frog or the carp for a considerable time.

A mixture of ether and blood, kept in a stoppered vessel for some time, became thick, assumed a greasy appearance, and was no longer fit for the experiment; neither could a satisfactory result be obtained on shaking blood with an excess of ether; for then the ether took up the water of the blood, and thus reduced that fluid to a state of thickness.

On pouring off the ether from a known quantity of blood with which it had been continuously stirred for twenty-four hours, and submitting the blood to a single washing with ether, I was astonished to find that from the two ethereal solutions I obtained quite as large a quantity of fat as I should have done by the repeated extraction of a corresponding portion of dried and finely-powdered blood with boiling ether. On treating pure liquid serum of the same blood in a similar manner, the quantity of fat obtained did not differ from the quantity obtained from the perfect blood, in a ratio sufficient to justify the supposition, that the capsules are composed of fat.

I can also confirm Hünefeld's observation respecting the influence of bile upon the blood. On the addition of fresh bile, the blood immediately becomes clear, and the corpuscles disappear. In consequence of the viscosity of ordinary bile, I experimented with pure bilin.

Upon the addition of a little partially dried bilin to the blood of man, the calf, the tench, or the frog, the fluid becomes, after a little stirring, thick, almost gelatinous, capable of being drawn out into threads, and no corpuscles can be seen in it. If a minute drop of frog's blood, in which the corpuscles have been thus dissolved, be brought in contact, and suffered to mix with a fresh drop of blood from the same animal, an interesting microscopic object is afforded. After the first intense action is over, the corpuscles are seen to move about slowly, or to be in a state of rest, and gradually to disappear. The solution of the capsule (not of the nucleus) occurs so instantaneously that the eye cannot trace the reaction. The nucleus always remains as a granular mulberry-like corpuscle. It becomes gradually paler and paler, enlarging itself visibly at the same time, and at last its existence can only be ascertained by its brightness. I have never succeeded in observing the decomposition of the nucleus into its constituent parts, which has been described by Hünefeld, although I have carefully repeated his experiments. I usually observed, however, that at those points where many corpuscles had disappeared, numerous minute points were visible, of which the larger ones displayed a lively molecular motion. In those instances in which the corpuscles resisted the solvent power of the bilin for a considerable time (possibly in consequence of the reagent being applied in too

dilute a state,) they often assumed very peculiar forms; appearing as if they were twisted, and extended longitudinally in one direction, or variously coloured in the interior. (*Vide supra*, p. 95.)

I have formerly noticed the solvent power of olive oil upon the corpuscles.¹ I shook a quantity of the blood of a calf, which had been allowed to flow from the vein into a vessel one quarter full of olive oil, until the blood was perfectly cool. No corpuscles could then be detected. Whipt blood exhibits the same phenomenon; but in this case it is requisite that the oil should remain for a longer period in contact with the blood. This fact has also been noticed by Magendie.²

b. The general chemical relations of the colouring matter of the blood (*Hæmatin.*)

The red colouring matter of the blood is contained, in all probability, in a state of solution in the corpuscles, an opinion which is also supported by Müller, Schultz, and Reichert. If, in the examination of frog's blood, one corpuscle be observed to move over another, the lower can be distinctly perceived through the upper one. Moreover, the instantaneous solution of the corpuscles by means of bilin supports this view; for, if their contents were gelatinous or solid, the act of solution would be observed to progress from the circumference to the centre, and would admit of being observed by the microscope.

Hünefeld³ seems to support the opinion that the colouring matter exists in an insoluble form, attached to the inner surface of the capsules. If, however, this were the case, the blood-corpuscles would appear more opaque than they do. The observations of Hünefeld and others show that the following substances heighten the red colour of the blood: cold water-extract of the flesh of rabbits and calves (having an acid reaction) communicates a vermillion colour to the blood. It becomes of a deep garnet red by the carbonate, cyanate, and nitrate of ammonia, and less intensely by the saliva, phthisical sputa, gonorrhœal matter, sweat, hydrocyanic acid, the carbonates of soda and potash, and bicarbonate of soda.

A brown tinge may be produced by the agency of several substances; for instance, by all free acids, by sugar of milk, oil of bitter almonds, ammonia, boracic acid, carbonate of magnesia, tartrate of potash, bromide of potassium, sulphate of magnesia, chloride of strontium, nitrate of strontia, lactate of iron, phosphorus, iodine, &c.

The alkalies, alkaline earths, and sulphuret of potassium produce a green tint. It becomes entirely decolourized by the action of coneine and oil of turpentine.

¹ *Pharmaceutisches Centralblatt*, 1839, p. 672.

² *Leçons sur le Sang, et les alterations de cet liquide*, par Magendie. Bruxelles, 1839, p. 244.

³ L. c., p. 104.

c. The general chemical relations of the nuclei of the blood-corpuscles.

The similarity of the constitution of the nuclei to coagulated fibrin has been long observed. Hünefeld,¹ however, conceives that corpuscles, instead of consisting of fibrin, are mainly composed of fatty matter (either cholesterin or some allied substance), combined with albumen, as occurs in the yolk of eggs. In this view I cannot coincide, although I fully believe that albumen and fat do take a very active part in the production of the blood-corpuscles. In this instance, the formative process has advanced so far that we can expect to find the original materials of formation present in only very small quantities. It is true that the fibrin and the blood-corpuscles contain a greater relative proportion of fat than the other constituents of the blood; yet in fibrin the proportion amounts to only 5%, and the fat cannot therefore be regarded as a preponderating constituent of this substance. That the fat is not actually cholesterin seems pretty clear from the fact of the ready solubility of the corpuscles in caustic potash.

The diameter of the nucleus is usually about one-fourth or one-fifth of the diameter of the blood-corpuscle. In the amphibia it varies from .002 to .005; in fishes, from .0016 to .0025; in birds, its length is about .002, and in the mammalia .0008 of a line.

I have made the following observations with regard to the nuclei in the blood of man,² the carp, and the frog. The nuclei in the frog appear, after the solution of the capsule and hæmato-globulin, as partly elliptical and partly cylindrical. After washing them for a day or two in order to remove the colouring matter and albumen, they assume a more spherical form, and most of them present a granulated appearance on the surface. I cannot, however, positively assert that granular cells were present, nor did I observe the nuclei separate into distinct portions during this treatment. The nuclei, even when moist, were not soluble in boiling ether. When dried, moistened with water, and then observed under the microscope, several nuclei were seen floating about, apparently unaltered; many were, however, connected together in such a manner as to prevent their whole outline from being apparent. Upon treating the dry nuclei with ether, appearances similar to those already described were perceived. Moist nuclei dissolved readily in caustic potash; if the solution be supersaturated with concentrated acetic acid, and heated, an imperfect solution of the matter, precipitated by the acid, occurs; a very small quantity of dilute hydrochloric acid will, however, readily dissolve the whole. On treating the filtered solution with tannin, a copious precipitate was thrown down; ferrocyanide of potassium

¹ *Der Chemismus*, u. s. w. p. 108.

² I allude to the nearly colourless sediment which may be obtained by washing blood with a large quantity of water, and which is found to contain lymph-corpuscles and fragments of capsules.

caused a mere turbidity, or very slight deposit. Similar observations were made on the nuclei of carp's blood, but the ferrocyanide of potassium caused less turbidity than in the former case. The nuclei of human blood are scarcely discernible in the viscid sediment. The effect of reagents was much the same as in the former cases.

Hence we are led to infer that the blood-corpuscles are chiefly formed of a substance closely related to the protein-compounds, although not identical with any of them: possibly the nuclei may be converted into fibrin, soluble in the liquor sanguinis, after the metamorphosis of the blood-corpuscles has been accomplished. On heating the nuclei on platina foil, a fatty smell is first observed, and then an odour resembling that of burning albumen. Upon heating them in a test-tube, and applying litmus paper, the red colour is soon changed to a strongly-marked blue. The ash has a reddish appearance, and consists of peroxide of iron, lime, and phosphoric acid.

*d. The general chemical relations of the plasma (*liquor sanguinis*.)*

The plasma of living blood exists as a clear fluid, in which the corpuscles are seen to float. If the blood has been removed for some time from the body, the fibrin separates from the plasma. This separation appears to take place simultaneously and uniformly throughout the whole of the blood. As the fibrin contracts, it entangles the corpuscles; the subsequent contraction tends to expel the serum, and thus the clot is produced. The clot, at first soft and gelatinous, becomes gradually more consistent, and ultimately appears as a mass, capable of a certain degree of resistance, and floating in the serum.

There are certain pathological conditions, under which the blood cannot hold the corpuscles in suspension. There is then formed, previously to the separation of the fibrin, a layer of yellow plasma above the sunken blood-corpuscles, in which (i. e. in the plasma,) upon the subsequent coagulation, a certain quantity of fibrin separates (*crusta inflammatoria*.)

In some observations on the blood of a cachectic horse, made during the summer, I found that the corpuscles sunk so rapidly in the tumbler in which the fluid was received, that a layer of plasma was formed, amounting to nearly two-thirds of the whole volume of the blood, previously to the coagulation of the fibrin. The fibrin, which was present in large quantity, then began to coagulate, and after some time a solid cylinder of coagulated plasma was formed, which resisted a considerable degree of pressure, and under which the uncoagulated blood-corpuscles were distributed.

In some pathological states the blood contains mere traces of fibrin; in these cases no clot is formed; we observe merely the separation of a few dark gelatiniform flocculi.

The coagulation of the plasma is a consequence of the cessation of the vitality of the blood; hence it occurs not merely in blood ab-

stracted from the living body, but after death, and under some peculiar circumstances, in the vessels themselves. It is independent of external influences, for it occurs equally in ordinary air, *in vacuo*, and in various gaseous atmospheres. It may be accelerated or impeded by certain agents, and may even be altogether prevented; the blood, however, when prevented from coagulating in this manner, is in a state very different from that in which it previously existed in the body, the fibrin having undergone a chemical change.

The retardation or prevention of coagulation.¹

Fresh blood becomes solid below 32°, without the coagulation of the fibrin, which however occurs after thawing.

The blood of frozen and apparently dead frogs remains fluid, and the same is the case in hibernating animals, in which the temperature of the blood is reduced to that of cold-blooded animals.²

The coagulation of the blood is retarded by contact with animal membranes; it will remain fluid in tied arteries for the space of three hours. Blood which has been infused into the cellular tissue will remain fluid for weeks. Schultz has observed that blood which has collected in the intestines remains fluid for a long time; moreover, the blood which has been abstracted by leeches does not coagulate, as long as it remains in the body of the animal.³

Gerhard, Hufeland, and Kielmeyer, have shown that blood through which an electric current is continuously passed remains fluid for a long time. Schubeler also showed that positive electricity hinders the coagulation of the blood; moreover, the blood of animals killed by electricity or lightning does not coagulate.

The following salts hinder the coagulation of the fibrin, according to Hewson,⁴ Schultz,⁵ and Hamburger's⁶ observations: sulphate of soda, chloride of sodium, nitrate of potash, chloride of potassium, acetate of potash, and borax, if they be added in the proportion of half an ounce to six ounces of blood. If, however, the blood be diluted with double the quantity of water, the fibrin coagulates. (Hewson.) The carbonates and acetates prevent the coagulation of the blood, in all degrees of concentration. With regard to the action of the sulphates, a concentrated solution appears to retard the coagulation; a dilute solution, on the contrary, to accelerate it. (Hamburger.) The same appears to be the case with respect to the tartrates and borates.

¹ [A full account of the various experiments by John Hunter, Davy, Prater, Scudamore, and others, on the effects of various agents upon the coagulation of the blood, to the period it was written, may be found in Ancell's seventh lecture "on the Physiology and Pathology of the Blood.—(Lancet, 1840.)

² Schultz, op. cit. p. 80.

³ L. c., pp. 64 and 81.

⁴ Disquisitio experimentalis de sanguinis natura. L. B. 1785.

⁵ Op. cit.

⁶ Experimentorum circa sanguinis coagulationem specimen primum diss. inang. auct. Hamburger. Berolini, 1839.

The following metallic salts impede the coagulation of the fibrin: sulphate of copper, ammoniacal-sulphate of copper, sulphate of the protoxide of iron, chloride of iron, ferrocyanide of potassium, acetate of lead, and tartrate of antimony and potash.¹

Magendie's² observations differ considerably from the above. He arranges in a tabular form³ the following salts which tend to impede the coagulation of the blood: the alkaline carbonates, nitrate of potash, and nitrate of lime. All observers agree that the free alkalies completely prevent the coagulation.

The observations of Schultz, Magendie, and Hamburger, show that dilute mineral and vegetable acids prevent the coagulation of blood, which however thickens, and assumes a syrupy or oily appearance. These statements have been confirmed by myself.

The following non-mineral reagents have been observed by Magendie to prevent or impede the coagulation of the fibrin: nitrate of strychnine, nitrate of morphine, and nicotine. This statement, as far as regards the nitrate of strychnine, has been denied by Hamburger.⁴

Hunter observed that the coagulation was retarded by the addition of a solution of opium, a statement however which is not confirmed by Hamburger. The latter observer notices the effect which is produced by the addition of bile, in preventing the coagulation.

Acceleration of the coagulation.

The coagulation of the fibrin is accelerated, or at any rate not impeded, by a temperature higher than that of the living blood. According to Hewson, it takes place most rapidly at from 114° to 120°. Scudamore and Schröder van der Kolk assert that the coagulation is accelerated by electricity and galvanic currents, which, however, is opposed to the previous observations of Kielmeyer and others. Contact with atmospheric air hastens the coagulation.

According to Hamburger, no influence, either in accelerating or impeding the coagulation, is exerted by sulphate of lime, chlorate of potash, or iodide of iron.⁵

According to Magendie and Hamburger, the coagulation is accelerated by acetate of morphine. The former observer states that water, a watery solution of sugar, the fluid of dropsy, Seidlitz and Vichy waters, alcohol, ether, and mannite; and the latter, that decoctions of digitalis, and tobacco, solution of tannin, iodine, solution of sugar, gum Arabic, starch, and fresh urine, have a similar effect.⁶

¹ Schultz remarked that hydrochlorate of ammonia, sulphate of potash, and sulphate of magnesia, retain the blood in a state of fluidity, and that even the addition of a large quantity of water does not produce coagulation. After the addition of sulphate of soda, the blood could only be prevented from gelatinizing by constant stirring, a step that was not requisite with the other salts.

² *Leçons sur le Sang.* Bruxelles, 1830.

³ Op. cit. p. 249.

⁴ Ib. p. 45.
⁵ Magendie observed that the coagulation is hastened by the addition of the chlorides of potassium, sodium, ammonium, and barium; of bicarbonate of soda, sulphate of magnesia, borax, nitrate of silver, iodide of potassium, and the cyanides of gold and mercury.

⁶ [A summary of Mr. Blake's experiments on the effects of various salts, &c. on the blood, is given in Williams's *Principles of Medicine*, page 99.]

ON THE CHEMICAL PHYSIOLOGY OF THE BLOOD.

On the formation of blood.

The formation of the blood, and especially of the blood-corpuscles has been made a subject of careful and laborious research by many of the best microscopic observers of the present age, amongst whom we may enumerate the names of Schultz, Baumgärtner, Valentin, Reichert, Wagner, and Schwann.

[As the physiological details connected with this subject belong strictly to the physiology rather than to the chemistry of the blood, we shall content ourselves with a brief statement of all that is known with any degree of certainty regarding this obscure and intricate process.

Capillary vessels are developed by the stellated union of a certain set of blastodermic or germinal cells; and no sooner are capillary or other vessels formed, than a kind of blood is found in them. The corpuscles of that blood differ from those of the adult in being considerably larger, more spherical and granular, and in containing a distinct nucleus. There is probably an external envelope. The granules unite or amalgamate, so as to form the coloured or clear part of the blood-corpuscle, while the nucleus remains. See fig. 2.]

Although much light has recently been thrown on the formation of the blood-corpuscle in the embryo, we are still unfortunately almost entirely deficient in positive information regarding the formation of the blood-corpuscles in the mature individual. That blood-corpuscles are formed in adults, cannot admit of a doubt; for we see that the mass of the blood, and consequently of the blood-corpuscles, is continually increasing from the moment that the blood is first produced in the embryo, up to the period of full corporeal development. Moreover, independently of any considerations founded on the increased mass of the blood, a continuous formation of blood-corpuscles is obviously necessary to compensate for the waste and consumption of blood dependent on the exercise of the vital functions. The immense quantities of extractive matters (abounding in nitrogen and carbon)—of urea, uric acid, bile, mucus, and fat, which are daily secreted in the urine, faeces, and mucous discharges, together with the considerable amount of carbon which is given off as carbonic acid in the process of respiration,—must all be refunded to the system by the blood. To this it may be objected that the supply takes place on the part of the plasma, which alone therefore would require to exist in a state of continuous increase, while the corpuscles coexist, and are coeval with the individual in whose blood they occur. Such a view is, however, at variance with all the phenomena of the higher stages of existence: for no tissue or portion of the body, solid or fluid, is allowed to remain unchanged or unendowed with vitality. The necessity for the consumption and reproduction of the blood-corpuscles has never yet been disputed, but various theories have been pro-

pounded by different physiologists regarding the seat of their formation and their mode of organic development or metamorphosis.

Hewson endeavours to show that the spleen is the principal organ in which the blood-corpuscles are formed, and that they are produced from lymph-granules. Although the functions of the spleen are not even at the present day properly determined, it is an established fact that the spleen may be extirpated, and the formation of blood not be impeded; moreover, the red colour of the lymph, upon which Hewson strengthens his opinion, has not always been observed.¹ Schultz² considers that the blood-corpuscles are formed in the lymphatic glands, and conveyed by the ductus thoracicus into the blood. He states that the chyle which is found in the vessels issuing from the glands, contains clear, round, oily vesicles, and granular lymph-corpuscles. The diameter of the granular lymph-corpuscles in horses and rabbits varies from .0005 to .0008 of a line; and they are so similar to the nuclei of the blood-corpuscles, as to render it very probable that the latter are derived from them. In the lymph of the ductus thoracicus of rabbits and horses, we find actual blood-corpuscles, as well as the transparent and granular lymph-corpuscles; these blood corpuscles, however, possess more tender, and not perfectly flattened capsules, and a much smaller amount of colouring matter than when they have arrived at maturity. They are consequently paler and more transparent than at a subsequent period, and the nucleus may be enclosed more or less closely in the capsule. The lymph-corpuscle and the nuclei of the blood-corpuscles present a very close analogy, for they both vary in size, and, to use Schultz's own words, "it cannot be doubted that the blood-corpuscles are produced by the formation of a coloured capsule around the lymph globules."³

These blood-corpuscles could not have been transmitted there by blood-vessels; their difference from the mature corpuscle, and their slight amount of colouring matter, are opposed to such a supposition. Since lymph-corpuscles also pass into the blood, the formation of blood-corpuscles from them in the blood-vessels cannot be denied; it may however happen that they are again conducted by the blood to the lymphatic glands, where their metamorphosis is completed. In a more recent work on the blood⁴ Schultz states that the coloured capsule of the blood corpuscle is principally formed in the process of respiration. There is much in favour of this view, for we know that the blood can only obtain its nutriment through the ductus thoracicus, and it seems obvious that the conditions necessary for the formation of the blood-corpuscles must be associated with the circumstance of the derivation of the nutriment from this source. Moreover, there can be no doubt that in consequence of the continuous

¹ J. Müller's *Handbuch der Physiologie*, vol. I, p. 573.

² *System der Cirkulation*, p. 37.

³ L. c., p. 45.

⁴ *Ueber die gehemmte Auflösung und Ausscheidung der verbrauchten Bluthäischen*. Hufeland's Journal, April, 1838.

supply of chyle which is afforded to the blood, the lymph-corpuscles would speedily predominate, unless they underwent some metamorphosis, and assumed another form; but in reality the number of lymph-corpuscles in the blood is comparatively small. Although the lymphatic glands may be regarded as in some degree the seat of formation of the blood corpuscles, it must by no means be supposed that the latter issue from these glands in a perfectly developed state; their ultimate maturity is obtained in the blood, and they aid in the support of its independent vitality. Henle, who likewise coincides in the view just given, as I know from a personal communication with him, has minutely studied the formation of the blood-corpuscle from the lymph-corpuscle, and the transitions of the latter to a state of maturity. He regards the lymphatic gland as the chief, although not the exclusive seat of formation of the blood corpuscles. Although the chyle does not contain a sufficient number of matured blood-corpuscles to allow us to recognise their presence by its external appearance, we must remember that during its continuous discharge into the subclavian vein, a considerable number of blood-corpuscles may in a certain time be conveyed into the blood: that the blood-corpuscles which are contained in the chyle are formed in the organs of chylification, and are not conveyed thither by arteries or veins, is clear from our knowledge of the connexions between the vascular and capillary systems.

It is pretty generally allowed that the process of respiration is essentially requisite for the further development of the young blood-corpuscles, after their formation in the lymphatic glands. J. Müller in his chapter on the formation of the blood, expresses himself to the effect that the contents of the lymphatics, namely, the clear lymph and the whitish chyle, are the materials for the formation of the blood, and that this formation is carried on not in any one particular organ, but under the combined influence of the vital functions generally. This view corresponds with the former, if in the materials for the formation of the blood we understand the young blood-corpuscles, (i. e. the lymph- and chyle-corpuscles which are to be changed into blood-corpuscles,) and the plasma, which is still almost destitute of fibrin. If, however, the lymph- and chyle-corpuscles are regarded as having no connexion with the genesis of the blood-corpuscles, then it is distinct from the previous views. Reichert in his work on Development, has said nothing respecting the formation of blood-corpuscles in the adult; but from a personal communication, I find that he regards the liver as the blood-preparing organ in adults, and the preparation of the blood as the principal function of that gland: the secretion of bile must then be regarded as a consequence of the metamorphosis that occurs during the above process.

On the forces that circulate the blood.

The due performance of the functions of circulation and respiration is as essential to the metamorphosis of the blood as it is to life itself.

Circulation commences in the foetus with the rhythmic movements of the heart.

Reichert¹ has observed in the incubated egg, that the only independently formed canals for the blood are the great vascular trunks directly connected with the heart; the other blood-vessels are, as it were, excavated by the force of the heart's action on the blood-cells in the loose cellular mass of the early embryo.

The action of the heart is the *primum movens* of the circulation. Burdach² observes that the vital action of the heart, which acts mechanically on the blood, and propels it in certain directions and courses, indicates most clearly that the heart comprehends within itself the elements of the circulating power, and that independently of its vital activity, the whole circle of phenomena appertaining to it results from its mere mechanical relations. The cause of the heart's action must be referred to the irritation produced in it by the living blood. Müller³ also considers that the blood is chiefly propelled by the rhythmic action of the heart.

The view taken by Schultz⁴ is different; he considers that the motion of the blood in the living body results from the joint influence of the blood and of the vessels reciprocally acting on each other, whose true nature can only be seen in the vital relations, and its aim in the circle of organic functions.

R. Wagner⁵ is inclined to believe that the blood is propelled not merely by the heart's action, but also by a certain electric attraction of the organs, by the influence of the nerves, and by a motive power inherent in the blood itself. Since the heart's action is occasioned by the irritation exercised upon that organ by the living blood, there can be no doubt that the reciprocating action of the organs and of the blood must influence the circulation. Schultz evidently undervalues the influence of the rhythmic motion on the circulation, when he limits the functions of the heart to the conveyance of arterial blood to the peripheral system, and to the conduction of venous blood back again, and regards the blood in the peripheral system as moving entirely independent of it.

The circulation is usually divided into the greater and the lesser. There is, however, in fact, but one circulation; and this is divided into the greater course, which proceeds from the left heart through the arteries of the body, and through the veins to the right heart, and into the lesser course, which reconducts the blood through the lungs from the right to the left heart.

On the process of respiration.

Respiration takes place through lungs, gills, tracheæ, or the integument.

Oxygen is indispensable for the process, although pure oxygen is

¹ Op. cit. p. 142.

² Op. cit. vol. 4, p. 163.

³ Op. cit. vol. 1, p. 163.

⁴ Op. cit. p. 244.

⁵ Zur vergleichenden Physiologie des Blutes, 1833, p. 70.

less conducive to health than a mixture of oxygen with a gas not detrimental to life, as nitrogen or hydrogen.

The proportions of oxygen and nitrogen that occur in atmospheric air are doubtless the most suitable for the respiration of the higher animals; viz. 21 parts of the former and 79 of the latter gas. In an atmosphere of pure hydrogen or nitrogen, a man would run the risk of suffocation in a very few seconds, not because these gases are themselves poisonous, but simply from the absence of oxygen.

Many gases produce a directly poisonous effect, and cannot be breathed even when mixed with oxygen; as, for instance, arsenic-rettetted hydrogen, sulphuretted hydrogen, phosphoretted hydrogen, carburetted hydrogen, carbonic oxide, cyanogen, chlorine, ammonia, and many others.

As a consequence of the process of respiration, the blood becomes chemically changed; this change is almost entirely confined to the blood-corpuscles, which in this independent act of metamorphosis represent exactly what we understand by the vitality of the blood.

Respiration in man and the mammalia is effected by the dilatation and contraction of the cavity of the thorax.

Since the diaphragm in a state of relaxation is arched, and in a state of contraction during inspiration becomes flattened, the cavity of the thorax is increased during inspiration, the surface of the lung follows the retreating walls, its volume becomes enlarged, and the atmospheric air rushes into its cells. The branches of the air-tubes ramify to an extraordinary degree in the parenchyma, and their most minute extremities terminate in vesicular dilatations, which do not communicate with each other, and whose walls are covered with the peripheral capillary network. From a calculation of Lieberkuhn,¹ it would appear that the whole surface of the ramifying air-tubes in man amounts to 1400 square feet, on which extraordinary surface the blood and atmospheric air are in contact with each other, (being separated merely by a moist, permeable membrane,) and the former absorbs the required amount of oxygen.

Davy calculates that the human lung after the strongest expiration still contains 35 cubic inches of air; after an ordinary expiration 108 cubic inches; after an ordinary inspiration 118, and after a very deep inspiration 240 cubic inches.

In ordinary inspiration and expiration (about 26 or 27 in the minute) the amount of air that is changed varies from 10 to 13 cubic inches.

According to Herbst, full-sized adults usually inspire from 20 to 25 cubic inches; persons of smaller stature 15 to 20. The volume of air inspired during each respiratory act is fixed by Allen and Pepys at 16·5, by Abilgaard at from 3 to 6, and by Thompson at 40 cubic inches.

The quantity of air that enters the lungs in the course of 24 hours is calculated by Davy at from 400,000 to 500,000 cubic inches, by

¹ Schultz, op. cit. p. 288.

Allen and Pepys at from 460,800 to 475,200, and by Thompson at as much as 1,152,000 or 52·5 pounds, the respirations in this case being 20 in the minute.¹

Atmospheric air once respired is lessened in volume; and the loss has been variously estimated by Berthollet, Pfaff, and Davy at from 1-27th to 1-100th of its bulk. Allen and Pepys, however, found the loss not more than 1-166th, or about 0·6%, and they looked upon the former as a mere error of observation.

The most important experiments regarding the changes which atmospheric air undergoes in respiration, are those of Allen and Pepys,² of Dulong,³ and of Despretz.⁴

The earlier experiments of Allen and Pepys showed that the quantity of oxygen lost was exactly replaced by the carbonic acid generated, and that nitrogen was given off.

In their later experiments, it appeared that more oxygen was absorbed than the quantity of carbonic acid expired accounted for; they were also further convinced of the accuracy of their former observations respecting the increased quantity of nitrogen which is expired. They caused animals to breathe an atmosphere of pure oxygen, and likewise of oxygen mixed with three times its volume of hydrogen. In the latter case a portion of the hydrogen disappeared, and was replaced by an equal volume of nitrogen.

The experiments of Dulong were conducted with great accuracy, and by means of apparatus expressly prepared for the purpose. They showed that more oxygen is consumed than is replaced by the carbonic acid formed. The quantity of oxygen thus lost, and not replaced by carbonic acid, amounted in the case of herbivorous animals to about 10% of the oxygen which was changed into carbonic acid; in carnivorous animals the minimum excess amounted to 20, and the maximum to 50%.

The observations of Despretz confirm the results obtained by Dulong, and likewise show that nitrogen is developed during respiration.

The following table presents a sketch of the results of the observations made by Despretz; the calculations are founded on the French litre:

	Air before the Experiment.		Air after the Experiment.			Excess of Oxygen over Carbonic Acid formed.	Nitrogen developed.
	Nitrogen.	Oxygen.	Nitrogen.	Oxygen.	Carbonic acid.		
Rabbits	37·914	10·079	38·743	6·023	3·076	0·980	0·839
Leverets	39·065	10·389	39·517	6·216	2·955	1·218	0·438
Guinea-pigs	37·957	10·089	39·023	6·790	2·688	0·707	1·066
Dog	37·649	10·008	39·022	4·424	3·768	1·806	1·374
Puppies	37·176	9·682	38·273	3·649	4·018	2·215	1·097
Tom Cat	37·630	10·055	38·354	7·125	2·060	0·870	0·594
Pigeons	37·662	10·012	38·372	6·826	2·451	0·735	0·710
Great Owl	38·027	10·109	38·754	7·483	1·601	1·085	0·727

¹ Gmelin's Handbuch der theoretischen Chemie, vol. 2, p. 1519.

² Schweiger's Journal, vol. 1, p. 182; and vol. 57, p. 337. Phil. Trans. 1809, p. 410.

³ Ib. vol. 38, p. 506.

⁴ Annales de Chimie et de Physique, vol. 26, p. 337.

The quantity of carbonic acid formed in the process of respiration in twenty-four hours in adults, and the amount of carbon contained therein, have been calculated as follows:

	Expired Carbonic Acid.		Carbon.	Consumed Oxygen.	
	Cubic inch.	Grains.	Grains.	Cubic inch.	Grains.
Lavoisier and Seguin	14930	8584	2820	46037	15661 French.
Menzies	31680	17811	4853	51480	17625 English.
Davy	39600	18612	5148	45504	15751 "
Allen and Pepys . . .				39600	13464 "

The large amount of carbon, from 11 to 13 ounces, (Davy, Allen, and Pepys,) that is thus carried off by the lungs in the twenty-four hours, does not accord with the other phenomena of nutrition; and Berzelius has calculated that it would require $6\frac{1}{2}$ pounds of solid food daily to make up for the carbon that is separated by the lungs alone, without taking into consideration the very considerable amount that is also removed by the urinary secretion. And further: when we consider that in most sorts of food the portion which is converted into chyle is much less than that which is carried off by the intestinal canal in the form of faeces, it becomes the more wonderful how so many persons can exist on a few pounds of daily food, the solid constituents of which must be very small, and of which only a still smaller part admits of assimilation; and we cannot help agreeing with Berzelius, that so large an excretion of carbon is inconceivable, and that in all probability there is some fallacy in the experiments.

Prout has made some interesting observations respecting the development of carbonic acid from the lungs at different periods of the day. He found that during equal spaces of time the minimum occurred during the middle of the night; towards morning it increased, and attained its maximum between 11 and 1 o'clock; it then gradually diminished till about 9 p. m., when it remained fixed at its minimum till 3 a. m. The quantity of carbonic acid was likewise found to increase by gentle exercise, especially at its commencement and when the barometer was low.

The mean amount of carbonic acid per cent. was 3.45. [A series of similar experiments has been published by Mr. Coathupe, which differ in several respects in their results from those of Prout.] They were continued for a week. The following is the result obtained:

	Carbonic acid per cent. of air expired.	
From 8 a.m. to 9 $\frac{1}{2}$.	4.37
10 a.m. to 12	.	3.90
12 noon to 1	.	3.93
2 p.m. to 5 $\frac{1}{2}$.	4.17
7 p.m. to 8 $\frac{1}{2}$.	3.63
9 p.m. to midnight	.	4.12—Mean 4.02.

Macgregor ascertained that the air expired by persons ill of confluent smallpox contained as much as 8 $\frac{1}{2}$ of carbonic acid. During

the eruptive fever of measles, it amounted to from 4 to 5½; and in proportion as the health was restored, the per centage was diminished to its natural standard. In chronic skin diseases an augmentation was likewise observed; and, in a case of ichthyosis, the mean per centage was 7·2; in typhus, according to Dr. Malcolm,¹ the formation of carbonic acid is diminished; in diabetes, no deviation from the normal standard could be detected.

The question of the quantity of carbonic acid expired by a person in twenty-four hours has lately become of peculiar interest, in consequence of its association with several problems of high physiological importance. Liebig has endeavoured indirectly to estimate the quantity by comparing the amount of carbon contained in the food consumed in the twenty-four hours, with the carbon of the excretions during the same period, and estimating the difference as the quantity separated by the respiratory process. He thus found that an adult, taking moderate exercise, expires daily on an average 13·9 ounces of carbon (more than double the quantity found by Lavoisier.)

Experiments have recently been made by Andral and Gavarret, Scharling, and Brunner and Valentin, with the view of ascertaining this point, and of elucidating the chemical bearings of this department of physiology. We shall endeavour to give, as briefly as possible, their most important results.

Absolute quantity of expired carbonic acid.

Andral and Gavarret expressed their results per hour. They are contained in the following table:

MALE SEX.									
Age.	Muscular development.	Carbon exhaled		Age.	Muscular development.	Carbon exhaled		grains	grains
		per hour.	grains			per hour.	grains		
8	Moderate	67·0		37	Moderate	164·7			
10	Very great	104·7		40	Very great	186·3			
12	Moderate	113·9		45	Very slight (mean of 4)	132·4			
12	Great	127·8		48	Good	161·7			
14	Moderate	126·2		50	Good	164·7			
16½	Good	157·0		54	Very great	163·2			
18	Good	169·4		59	Moderate	154·0			
20	Good	166·3		60	Extraordinarily great	209·4			
24	Moderate (mean of 2)	176·6		63	Extraordinarily great	190·9			
26	Extraordinarily great	{ 217·1		64	Slight	133·9			
26	Moderate	{ 217·1		68	Moderate	147·8			
28	Good	169·4		76	Slight	92·4			
32	Good	190·9		92	Extraordinarily great	135·5			
33	Moderate (mean of 6)	176·6		102	Extremely diminished	90·8			
		164·7							

¹ London and Edinburgh Monthly Journal of Medical Science, 1843, page 1.

FEMALE SEX.

Periods of life.	Age.	Muscular develop- ment.	Carbon exhaled per hour. grains	Periods of life.	Age.	Muscular develop- ment.	Carbon exhaled per hour. grains
Prior to the appearance of the catamenia.	10	Good .	92·4	After cessation of catamenia.	38	Moderate	190·3
	11	Good .	95·4		42	Good .	127·8
	13	Great .	97·0		44	Very great	152·4
	15 $\frac{1}{2}$	Very great .	109·3		49	Moderate	113·9
	15 $\frac{1}{2}$	Moderate .	97·0		52	Moderate	115·5
	19	Very great .	107·8		56	Moderate	109·3
	22	Good .	103·1		63	Moderate	106·2
	26	Slight .	92·4		66	Moderate	104·7
	26	Moderate .	97·0		76	Very great	101·4
	32	Moderate .	95·4		82	Moderate	92·4
During menstrual life.	45	Moderate .	95·4	3 months pregnant 5 mo. do. 7 $\frac{1}{2}$ mo. do. 8 $\frac{1}{2}$ mo. do.	42	Good .	120·3
					32	Good .	126·7
					18	Slight .	112·4
					22	Good .	128·3

It is thus seen that, in general, the amount of carbonic acid expired by both sexes increases with age up to a certain point—the 40-45th year, and then diminishes; that the quantity of carbonic acid expired increases with the development of the muscular system; that women expire less carbonic acid than men; that the formation of carbonic acid attains its maximum at the commencement of menstruation, and then experiences no further increase, except in the pregnant state, until the cessation of menstruation, when an increase again takes place. On an average, an adult male, of moderate constitution, exhales from 160 to 170 grains of carbon per hour; an adult female in the unimpregnated state, from 100 to 110 grains; during pregnancy, 125 grains; and after the cessation of the catamenia, from 116 to 130 grains. Dumas also found 154 grains per hour as the average quantity of carbon exhaled by an adult male.

Scharling's experiments were made on the following individuals: 1st, a male, æt. thirty-five, weighing 191 lbs.; 2d, a male, æt. sixteen, weighing 115 $\frac{1}{2}$ lbs.; 3d, a soldier, æt. twenty-eight, weighing 164 lbs.; 4th, a girl, æt. nineteen, weighing 111 $\frac{1}{2}$ lbs.; 5th, a boy, æt. nine and three-quarters, weighing 44 lbs.; and 6th, a girl, æt. ten, weighing 46 lbs. The carbon exhaled per hour amounted to—

No. of the person.	Amount of carbon. grains.	Remarks.	No. of the person.	Amount of carbon. grains.	Remarks.
In June when very hot.	145	Fasting	October.	167·7	2½ hours after breakfast
	190	{ After breakfast and a walk		180·8	2 hours after dinner
	130	Hungry		3.	Asleep
	165	2 hours after dinner		137·8	Fasting
	160	After tea		111·9	{ Fasting, after breakfast and work
	100	Whilst asleep.		159·4	After dinner
				188·9	3 hours after dinner
In June when very hot.	114	Sleepy		194·7	After work
	144·2	Fasting		178·3	Whilst asleep
	139·8	Fasting and hungry		122·3	
	177	{ Half an hour after break- fast	4.	98·9	Whilst eating
			In	91·3	Fasting

No. of the person.	Amount of carbon. grains.	Remarks.	No. of the person.	Amount of carbon. grains.	Remarks.
October.	92-6	After supper		117-0	1 hour after dinner
	133-8	1 hour after breakfast		108-9	Whilst eating
5	76-2	Fasting	6.	65-5	Whilst asleep
In	91-8	Whilst at breakfast	In	95-3	After breakfast
Autumn.	113-8	After breakfast	Autumn.	103-0	After dinner
	119-3	1 hour after dinner		99-0	Shortly after tea
	84-5	2 hours after supper		75-1	Whilst asleep
	74-8	Whilst sleepy.			

Supposing that adults sleep seven, and children nine hours per day, the amount of carbon consumed is on an average—

	In twenty-four hours.	In one hour.
1.	3380 grains	141 grains.
2	3455	144
3.	3692	154
4.	2555	106
5.	2050	86
6.	1932	80

It is thus evident that the quantity of carbonic acid expired is very variable, and that it may be altered by many circumstances.

Hunger and rest diminish, satiety and labour increase it. It is greater during the day than the night, in the proportion of 1.237 to one. If the expired carboic acid be estimated in relation to the weight of the body, it is found that children give off a proportionally greater amount of this gas than adults. In some forms of disease, the amount of expired carbonic acid falls below the standard; it seems, in a state of health, to vary directly with the activity of the circulation.

The influence of muscular activity on the amount of carbon consumed, has been clearly shown by some experiments made by Dr. Hofmann during a pedestrian tour. His diet was simple and scanty, he took no drink, walked during the whole day, weighed all his food and every excretion that could be weighed (even the nasal mucus,) as well as himself; he then found that the weight lost by the body was never equalled by the excess of the excrements over the food, and that there was a constant loss of matter by the skin and lungs, which amounted to more than 1 lb. We must pass over the details of his experiments. Brunner and Valentin found that the weight of carbon they consumed per hour varied from 134 to 170 grains, and averaged 160. The volume of expired carbonic acid per hour, on an average, was equal to 21.8 litres,¹ and the entire volume of the air expired per hour on an average equal to 540 litres. These results agree well with those of the earlier observers. When the corrections for moisture are made, the quantity of carbon expired per hour is equal on an average to 172 grains, and of carbonic acid 23.5 litres.

¹ [The litre is a little larger than the English wine quart; the litre being equal to 1.028, and the quart to 57.75 cubic inches.]

B. Relations of the constituents of the expired air to the theory of respiration.

On this point Brunner and Valentin only have experimented. They found—

Individual.	No. of experiments.	Volume per cent.			Volume per cent. in relation to the atmosphere.		
		Mean of CO ₂ .	O.	N.	Disappeared O.	Difference of N.	
Brunner	12 exp. 1st series	4.396	16.007	79.547	4.720	+	0.362
	4 exp. 2d "	3.825	16.306	79.869	4.508	+	0.683
Thomas	4 exp. 1st "	4.673	15.895	79.432	4.920	+	0.329
	2 exp. 1st "	4.316	16.143	79.541	4.671	+	0.356
Valentin	12 exp. 2d "	4.641	15.783	79.576	5.032	+	0.391
	Total average	4.380	16.033	79.587	4.783	+	0.402
Weight per cent.							
Brunner	12 exp. 1st series	6.522	17.428	76.050	5.582	—	0.940
	4 exp. 2d "	5.749	17.735	76.516	5.275	—	0.474
Thomas	4 exp. 1st "	6.975	17.165	75.860	5.845	—	1.130
	2 exp. 1st "	6.458	17.481	76.061	5.529	—	0.929
Valentin	12 exp. 2d "	6.945	17.099	75.965	5.920	—	1.025
	Total average	6.546	17.373	76.081	5.637	—	0.909

It is thus evident that the variations observed in the amount of nitrogen are entirely within the errors of observation, and the nitrogen may be disregarded in the process.

Again, the expired air contains a volume of carbonic acid, which is but little less than the volume of oxygen which has disappeared, (therefore the weight per cent. of the carbonic acid is necessarily somewhat greater than that of the absorbed oxygen, and thus also the difference of nitrogen appears positive as regards volume, but negative as regards weight;) so that all the oxygen absorbed reappears as carbonic acid, except a small quantity consumed in the body for other purposes. Now, according to Graham's law of the diffusion of gases, when they are separated by an animal membrane and are under equal pressure, they become mixed inversely as the square roots of their densities; consequently, 1.17585 volume of oxygen is absorbed for one volume of expired carbonic acid. Comparison of the figures shows it that the mixture of the two gases in respiration takes place entirely according to the law of diffusion of gases; for the most accurate method of experimenting gave results, in which the figures obtained for the carbonic acid and absorbed oxygen, almost exactly agreed with those reckoned according to the law of the diffusion of gases:

CO ₂ .	Volume per cent. of the expired air.		O.	N.	Oxygen absorbed.	Carbonic acid calculated.	Difference.
	O.	N.					
3.650	16.270	79.185	4.690	3.994	+	0.144 per cent.	
3.503	16.034	79.185	4.931	4.199	+	0.606 "	
3.949	16.090	79.185	4.887	4.162	+	0.213 "	
3.777	16.090	79.185	4.914	4.192	+	0.415 "	
3.759	16.095	79.185	4.922	4.192	+	0.433 "	
4.483	15.328	79.185	5.608	4.853	+	0.370 "	
4.752	14.733	79.185	6.362	5.418	+	0.660 "	
4.588	14.852	79.185	6.253	5.325	+	0.737 "	

In respiration, which is thus a purely mechanical process, the inspired air is first warmed to 99°.5, and saturated with moisture at

this temperature, which is rapidly accomplished on account of its extensive distribution. It then experiences a simple diffusion; the nitrogen remains entirely unaffected; 1·1742 volume of oxygen is absorbed, and replaced by 1 volume of carbonic acid which is expired; or for each volume of oxygen absorbed ·8516 volume of carbonic acid appears. In consequence of the accuracy with which the law of diffusion is here observed, the most minute portion only of other gases is absorbed or expired.

That hydrogen, carburetted hydrogen, and carbonic oxide gases are not contained in the expired air, the authors have shown by some direct experiments; but small quantities of organic matters are evolved during respiration, as is shown by sulphuric acid, through which expired air has been made to pass, being always coloured red.¹

Various opinions have been promulgated respecting the formation of carbonic acid in the blood. The most natural and probable is that of Lagrange and Hassenfratz, who maintain that the blood takes up oxygen in the lungs and retains it in a state of solution. The blood-corpuscles absorb from this constant source a due supply of oxygen for their change.

The metamorphosis occurs in the peripheral system, and, for the most part, in certain organs, as, for instance, the kidneys. The blood-corpuscles give up the carbonic acid, thus formed, to the blood, and it is thrown off by the lungs. It must be remembered that blood always contains carbonic acid and oxygen, but arterial contains more of the latter and less of the former than venous blood; also, that the whole of the carbonic acid is not separated by the lungs, although, when the blood reaches those organs, it is perfectly free from oxygen.

Although the atmospheric air and the circulating fluid are not brought into absolute contact, there is no impediment to their mutual action. The absorption of the air through the humid membrane that surrounds the parenchyma of the lungs is facilitated by the immense extent of surface presented, over the whole of which a thin stratum of blood is distributed, and simultaneously exposed to the atmospheric influence. The permeability of the soft tissues, especially of the membranes, by fluid and gaseous substances, is a well known fact. It is in accordance with this law that atmospheric air finds its way into the blood. Dark red blood, enclosed in a moist bladder, soon assumes a bright red tint; a gas enclosed in a similar receptacle is found, after some time, to be partly displaced by atmospheric air. These are mere illustrations of the same principle. If the opinion that has just been given be correct, then carbonic acid and oxygen must be present both in venous and arterial blood. Numerous experiments have been instituted with the view to determine this point.

By submitting 12 ounces of the venous blood of a calf to a heat of

¹ [For further information on this subject, the reader is referred to Valentin's *Lehrbuch der Physiologie*, 1844, vol. 1, pp. 507-550, or to an excellent abstract that appeared in the *Chemical Gazette*.]

200°, Sir H. Davy obtained 1·1 cubic inch of carbonic acid, and 0·1 of oxygen, and the experiment has been confirmed by Brande and Vogel. Stromeyer, Bergemann, Müller, and others have failed in obtaining carbonic acid from blood in this manner. Brande and Vogel found that blood placed *in vacuo* developed a gas which contained some carbonic acid, and their statement is confirmed by Home, Bauer, and Reid Clanny, while J. Davy,¹ Mitscherlich, Tiedemann, Gmelin, and Müller failed in observing any development of carbonic acid under the air-pump.

Hoffmann and Stevens could not obtain carbonic acid either by the application of heat or by the air-pump; but they observed that if freshly-drawn blood be shaken with hydrogen, carbonic acid is then evolved. Another experiment in favour of the existence of carbonic acid in the blood has been instituted by Müller. Nysten and Collard de Martigny made animals inhale gases entirely devoid of oxygen, and observed the formation of carbonic acid. Müller and Bergemann made frogs breathe pure hydrogen and nitrogen, and observed that, after the animals had remained in these gases from 6 to 22 hours, they had expired a quantity of carbonic acid, varying from 0·25 to 0·83 of a cubic inch.

Magnus has published a series of accurate experiments which must be regarded as quite decisive respecting the amount of carbonic acid and oxygen in arterial and venous blood. He passed a current of hydrogen through recently drawn blood, and found that carbonic acid was given off in a constantly decreasing ratio. He likewise analyzed the whole of the gas that he obtained from the blood, and found its composition as follows:

Volumes in cubic centimeters.							Gas.
Blood of a horse	-	-	125	-	-	yielded 9·8	{ 5·4 CO ₂ 1·9 O 2·5 N 8·8 CO ₂
Venous blood of a horse	-	-	205	-	-	12·2	{ 2·3 O 1·1 N 10·0 CO ₂
Ditto	-	-	195	-	-	14·2	{ 2·5 O 1·7 N 10·7 CO ₂
Arterial blood of a horse	1	-	130	-	-	16·3	{ 4·1 O 1·5 N 12·4 CO ₂
Ditto	-	-	122	-	-	10·2	{ 2·2 O 1·0 N 7·0 CO ₂
Venous blood of the same horse	-	-	170	-	-	18·9	{ 2·5 O 4·0 N 9·4 CO ₂
Arterial blood of the calf	-	-	123	-	-	14·5	{ 3·6 O 1·6 N 7·0 CO ₂
Arterial blood of the calf	-	-	108	-	-	12·6	{ 3·0 O 2·6 N

¹ [Dr. Davy has recently shown that gas is frequently, although not invariably, disengaged both from venous and arterial blood *in vacuo*. *Researches, Physiol. and Anat.* vol. 2, p. 153.]

	Volumes in cubic centimeters.	Gas.
Venous blood of the same calf	153	10.9 CO. 1.6 O 1.3 N
Ditto	140	6.1 CO. 1.0 O 0.6 N

From these experiments it follows, 1st, that carbonic acid, oxygen and nitrogen exist both in arterial and in venous blood; and, 2dly, that the quantity of oxygen is greater, and the quantity of carbonic acid less in arterial than in venous blood, a fact which confirms the opinion we have expressed regarding the formation of carbonic acid and the theory of respiration generally.

The bright colour which is communicated to the blood by oxygen, as well as the dark shade that is induced by the transmission of carbonic acid through it, are the actual shades of colour that we see in arterial and venous blood. Moreover, when blood has been rendered artificially venous in this way, it may be rendered arterial in its colour by agitation with a certain quantity of oxygen, and we can then obtain from it a mixture of oxygen and carbonic acid.

We have now enumerated the most interesting phenomena in reference to the expired air. We have already noticed the circumstance that nitrogen is expired. It follows naturally that this gas, which forms the principal constituent of the atmosphere, should be inhaled; and according to Edwards there is a sort of compensation between the amount of exhaled and inspired nitrogen, so that the quantity of this gas in the atmosphere remains fixed, the amount of expired nitrogen predominating at one time, and of inspired nitrogen at another. According to Berzelius, the portion of nitrogen taken up by the blood is only changed when the blood comes in contact with a gas which either contains no nitrogen or which possesses it in a greater ratio than atmospheric air. Nitrogen is therefore evolved from the blood during the inspiration of oxygen or hydrogen, and the circulating fluid is then found to contain a greater proportion than usual of oxygen or hydrogen; but if nitrogen is inhaled, an excess of this gas is found in the blood, while oxygen and carbonic acid are evolved in accordance with the known law of the diffusion of gases.

In the air after expiration we always find a greater or less amount of watery vapour. According to Menzies, an adult man, in the course of twenty-four hours, gets rid, in this manner, of 2880 grains of water. Abernethy fixes the amount at 4320; Thompson at 9120; Hales at 9792; and Lavoisier at as much as 13,704 grains. This water exhales from the blood which is circulating in the bronchi and cavity of the throat, and contains some animal matter which causes it to decompose speedily. Alcohol, ether, and substances of that nature are removed from the blood by the lungs, at least in part; for after they have been taken, their odour may be distinctly recognised in the breath. Sulphuretted and phosphuretted hydrogen, if injected into a vein, are easily recognised in the breath by the odour; and

phosphuretted oil is applied in a similar manner, dense white vapours of phosphorous acid are speedily exhaled.

Respiration of the fœtus and of animals.

As the function of respiration in the embryo of the mammalia cannot be carried on by the lungs, an equivalent is supplied to them by the influence of the maternal fluids on those of the fœtus, in the placenta. Anatomical investigations have shown, that it is impossible for the blood of the mother to be transmitted unchanged into the fœtus; nutriment and arterial blood can only make their way into the foetal system through the medium of cells.

In the umbilical cord there are two vessels which convey venous blood from the fœtus to the placenta, and there is one that conducts arterial blood from the placenta to the fœtus. The changes which are effected in this manner in the foetal blood are not so obvious as if they had occurred in the ordinary manner in the lungs: in fact it is by no means easy, or indeed always practicable, to detect any difference in the colour of the arterial and venous foetal blood. The change, however, such as it is, is of the highest importance to the fœtus, since it dies if the umbilical cord be tied before birth. The anatomical peculiarities in the circulating system of the fœtus are too well known to require any description.

In the embryo of birds the respiration is carried on during the latter stages of development, by the allantöis, an extremely vascular membrane, over which the left umbilical artery is especially distributed. The embryo is ultimately entirely enclosed in the *allantoide* (the *chorion* of V. Baer,) and is intimately connected with the membrane of the shell. The mutual action of the allantoide and the atmosphere, takes place directly through the membrane of the shell, and the shell itself, and thus it may be regarded as a proper respiratory organ, whose development has corresponded throughout with that of the embryo.

In birds, the lungs do not occupy the whole of the thoracic cavity, but are placed in its farthest extremity: the thoracic and abdominal cavities are not separated by a diaphragm. Openings are situated on the surface of the lungs which admit the air from those organs into the large cells situated around the pericardium and between the viscera of the abdomen: the air can pass from these cells even into the cavities of the bones.

Respiration is conducted in fishes much on the same principle that it is in the fœtus of the mammalia. The venous blood is conveyed to the gills, where it circulates in the capillaries, and absorbs oxygen and nitrogen from the air which is contained in the water, and in this way it becomes arterialized. Humboldt and Provençal have carefully studied the process of respiration in fishes, and have proved that they take up oxygen and nitrogen from the air which is diffused through the water, and that they exhale carbonic acid; that the quantity of oxygen which they absorb is more than is replaced

by the carbonic acid expired; that fishes absorb oxygen from boiled water which has been subsequently impregnated with half its volume, but that they only survive in it for a short time; and, lastly, that they die in water from which the air has been removed, or in which they have respired for any time.

The water (from the Seine in which these experiments were conducted contained from .0266 to .0287 of its volume of atmospheric air, of which from .306 to .314 was oxygen. The amount of carbonic acid varied from .06 to .11 of the volume of atmospheric air.

The water was enclosed in bell-glasses over mercury, through which the fishes were introduced into it. In experiments with tenches they observed, that from 100 parts of atmospheric air there were abstracted 22.8, 13.6, 23.4, 15.5, 17.4, 22.8 parts, the variations depending on the duration of the experiment and the number of the fishes. The ratios of the consumed oxygen to the carbonic acid formed, were as 1 to .57, .80, .91, .20, and .50, while the ratios of the consumed oxygen to the consumed nitrogen were as 1 to .43, .87, .40, .19, .71, and .63. The inequality of these ratios indicates, as Berzelius remarks, the varying power with which fishes act upon the air on different days, at different seasons, and possibly in different conditions of health.¹

The amount of oxygen consumed by fishes is much less than would be required for warm-blood animals of equal bulk,² and their temperature is very little above that of the surrounding medium. When breathing free atmospheric air, they do not consume more oxygen than in their native element.

Fishes absorb oxygen and exhale carbonic acid, not merely with their gills but with the whole surface of their body, as long as they are surrounded with water impregnated with atmospheric air. This fact was proved by Humboldt in the following manner. He passed a cork collar, covered with waxed cloth, over the head of a fish, which was then introduced into a vessel filled with water, and the vessel being closed by a cork collar, which was so adjusted that the head and gills of the fish did not come in contact with the water in the vessel. Fishes thus treated lived five hours, and the water in the vessel underwent the changes usually produced by respiration.

Ermann found that the air, in the swimming-bladder of lake fish, is deprived of a considerable portion of its oxygen. Biot, on the contrary, found in the swimming-bladder of those marine fishes that inhabit deep waters, more oxygen than nitrogen. Humboldt and Provençal observed that after the removal of the swimming-bladder fishes continued to absorb oxygen, but that they did not form any carbonic acid; they regard it, however, as doubtful whether this phenomenon is due to the pathological condition of the animal, or to the absence of the swimming-bladder.

¹ Thierchemie, p. 140.

² Treviranus estimates the amount at about 50% less than warm-blood animals of equal bulk would consume. His conclusions are based on the experiments referred to in the text.

Insects can live for a long time under the receiver of the air-pump, in a rarified atmosphere; if, however, their stigmata be closed with oil, they speedily die. The researches of Scheele, Vauquelin, and Hausmann show that in the respiration of insects a portion of the oxygen of the atmospheric air is converted into carbonic acid.

Treviranus has observed that the amount of oxygen which is taken up is frequently twice as great as is required for the production of the carbonic acid formed, and that insects always develop nitrogen. Thus a honey-bee, confined in an atmosphere of 272 cubic inches, consumed 13.5 of oxygen, while it only yielded 8.3 of carbonic acid, and 5.3 of nitrogen.

The experiments of Spallanzani and Hausmann tend to prove that the changes produced by worms on the atmospheric air in which they are confined are similar to those effected by insects.

On the metamorphosis of the blood.

All our conceptions of organic life are associated with the idea of continuous change of substance. A constant metamorphosis is going on in the living blood, which, in fact, may be regarded as the most obvious manifestation of its vitality.

When it ceases to undergo this metamorphosis, it dies; indeed the very act of vital annihilation is attended with a change in the blood, which we regard as an indication of its plastic power. As, however, life in every manifestation of its varying forms is dependent on certain conditions, and cannot exist when they are infringed, so it is with the vitality of the blood; for although there is doubtless an actual inherent power in the blood, it can no longer act when it is deprived of the condition requisite for its maintenance, namely, the reciprocal action of the organism. The blood is not the only portion of the body that undergoes this change; every organ and tissue is subjected to a similar metamorphosis, which is presented to us under the general phenomena of nutrition and consumption, (or waste,) and which is dependent on, and effected by, the blood alone; but since the various tissues present a different chemical composition, and since the different organs separate different matters from the blood, it is obvious that they cannot all modify the circulating fluid in the same manner, but that the metamorphosis must vary in some degree with the influence of the nervous system. Two conditions are essentially requisite for the metamorphosis of the blood, namely, circulation and respiration, inasmuch as, without them, the blood would not be brought in contact with the oxygen, which is necessary for the existence of life; and the more completely these functions are discharged, the more perfectly will the due changes in the blood be effected: if, on the contrary, the blood is detained in any part of the body, or cannot enter the sphere of atmospheric action in the lungs, the metamorphosis can be only imperfectly effected.

We know, from the investigations of Schwann and Reichert, that

all the tissues of the animal body are composed of cells, and that nutrition and growth of the organs and tissues is conducted by the production of new cells, appropriate for each individual organ, developing themselves at every point where the substance from which they are formed, viz. the blood, is conveyed; that these cells, by their organic formation, effect a change in the nutritious plasma, by appropriating from it matters homologous to themselves, and that the cells are finally consumed or dissolved, as is obvious from the general phenomena of the circulation. The nutrition and consumption of the tissues of the animal body in the general process of life is, consequently, the product of the nutrition and consumption of the cells which constitute those tissues. Since the capillaries are distributed over every particle of each individual tissue, and since their walls are composed of cells, which can communicate and impart the plasma to the adjacent cells, the plasma can be universally distributed, and the reciprocal action between it and the cells of the various organs ensured.

In what manner the cells act upon the nutrient fluid we are not able to understand, but there can be little doubt that they, or (which amounts to the same thing) the organs and tissues which they constitute, produce a dialytic, catalytic, or, as Schwann terms it, a metabolic change on the plasma of the blood. The products of these influences must necessarily consist of certain chemical compounds, formed in very different ways, and varying in their nature in accordance with the activity of the nervous power. The high atomic numbers of those animal substances which are of the most importance in nutrition, as the protein-compounds and fats, render the existence of numerous decompositions extremely probable. In vegetable chemistry we find whole classes of substances transmutable, one into the other, in which the same radical, consisting of carbon and hydrogen, is combined with different atoms of water, or of water and oxygen: I need only refer to woody fibre,¹ starch, gum, sugar, and lactic acid. We have sufficient grounds for assuming the existence of similar radicals in the chemical compounds of the animal body; and if we knew more of the composition of the extractive matters, we should doubtless find a radical common to all of them. In many of these decompositions, which are extremely varying in their nature, oxygen is undoubtedly absorbed, and carbonic acid evolved, as indeed we see in the process of respiration. Oxygen combines not merely with carbon; it may also enter into combination with hydrogen and form water, or with a binary or ternary radical, which it would oxidize. Hydrogen and oxygen may, further, be either separated from or taken up by these compounds, in the proportions in

¹ [Woody fibre (lignine)	$C_{12}H_8O_3$	$=(C_{12}H_8)O_2$
Starch - - - -	$C_{12}H_{10}O_{10}$	$=(C_{12}H_8)O_2 + 2HO$
Gum - - - -	$C_{12}H_{11}O_{10}$	$=(C_{12}H_8)O_2 + 3HO$
Cane Sugar - - - -	$C_{12}H_{10}O_{10}$	$+(HO)=(C_{12}H_8)O_2 + 3HO$
Grape or diabetic sugar - - - -	$C_{12}H_{12}O_{11}$	$+ 3HO=(C_{12}H_8)O_2 + 6HO$
2 eq. Lactic acid - - - -	$C_{12}H_{10}O_9$	$+ 2HO=(C_{12}H_8)O_2 + 4HO]$

which they form water. Thus quaternary compounds may be split into several quaternaries with the same or a different radical, or into quaternary and ternary compounds, &c. These must, however, be regarded as mere possibilities, which, unless kept in check by experiment, are capable of indeterminate extension.

One of the most important conditions for the reciprocal action between the cells of organs and the nutrient fluid is a proper degree of warmth; the requisite temperature varies in different classes of animals, but its range is limited within very narrow bounds, above or below which the action is impeded, or even destroyed, and death then ensues. If, therefore, we should regard the conditions of temperature as independent of the organism, and unconnected with the phenomena of life, these phenomena would be unavoidably and perpetually disturbed, and the due course of the organism altogether destroyed.

The conditions for the production of a due temperature are therefore based on the vital phenomena themselves, and in accordance with the principles of adaptation that are observed in the animal organism, it is developed by those very processes for which its existence is indispensably necessary.

On animal heat.

The temperature of every animal is higher than that of the surrounding medium. The temperature of the human body in those internal parts which are most easily accessible, such as the mouth and rectum, is usually between $97^{\circ}7$ and $98^{\circ}6$. The temperature of human blood varies from $100^{\circ}6$ to $101^{\circ}75$ in a state of health, but in disease it may rise to 106° or 107° . In morbus cœruleus and in cholera the temperature falls considerably: in the former the hand could only raise the thermometer to $78^{\circ}8$, and in the latter, the heat of the mouth raised it only to $78^{\circ}8$, and in another experiment to 77° . In healthy persons the temperature is said to attain its maximum during the day, and to fall from $1\cdot8$ to $2\cdot7$ degrees during sleep. In warm climates Dr. Davy found the temperature of the interior of the body $2^{\circ}7\cdot3^{\circ}6$ higher than in temperate climates.

Tiedemann¹ has given the following table regarding the temperature of birds, which is higher than that of any other class of animals.

	Degrees.
Great titmouse - - - - -	111-25
Swallow - - - - -	111-25
Fringilla, different species - - - - -	111-25 to 107
Anas, different species - - - - -	111 to 106
Common hen - - - - -	109-94 to 103-99
Falco, different species - - - - -	109-74 to 104-5
Pigeon - - - - -	109-58 to 106-7
Raven - - - - -	109-23 to 105-99

¹ Tiedemann's Physiologie, vol. 1, p. 454.

	Degrees.
Vulture	107.49
Common cock	103.78 to 102.99
White Game	102
Gull	100

Tiedemann and Rudolphi have also made an extensive series of observations regarding the temperature of the mammalia. The following is derived from their tables:

	Degrees.
Bat (<i>Vesperilio pipistrellus</i>)	106 to 105
Squirrel	105
Sheep	104 to 100.4
Ox	104 to 99
Rabbit	104 to 99.46
Ape (<i>Simia nigra</i>)	103.86
Cat	103.6 to 98.6
Bat (<i>Vesperilio noctula</i>)	102
Dog	101.3 to 99.3
Guinea-pig	100.4 to 96.37
Hare	100
Elephant	99.25
Horse	98.24 to 97

There is no very great difference between the cetacea and the other mammalia in respect to their temperature. The temperature of the seal and of the Greenland whale has been determined at 104°, and that of the porpoise has been found to vary from 99°.5 to 95°.9. The temperature of the amphibia differs very slightly from that of the surrounding medium. Czermack¹ found that the temperature of a proteus was 63°.5° when that of the air was 55°.4, was 68°.25 when the temperature of the air was 63°.5, and was 65° in water at 55°; in water of which the temperature was 44°.4, the temperature of a frog was 48°. Dr. Davy found the temperature of a snake 88°.46 in air of 81°.5, and 90° in air of 82°.94; the temperature of testudo midas was, 84° while that of the air was 79°.5.

The temperature of fishes appears, from the experiments of John Hunter, Dr. Davy, Broussinnet, and others, to be from .7 to 2.7 degrees above that of the surrounding water.²

It must be regarded as an established fact, that a certain temperature is necessary for the continuance of animal life, and that the source of this temperature must be sought for within the organism, and must be looked upon as a consequence of life itself. The production of heat cannot, however, be so properly ascribed to any of the collective phenomena of life, as to the chemical processes, which are known to develop warmth, and the action of which we see in the metamorphoses; and on the other hand a certain degree of animal

¹ Baumgärtner's und Ettinghausen's Zeitschrift für Physik und Mathematik, vol. 3, p. 385.

² [The theory of respiration, as the source of animal heat, invented by Lavoisier and Laplace, as well as the critical experiments by which that theory was tested by Dulong and Despretz, are too well known to require repetition; neither need we devote any space to the influence of the nerves on the generation of heat. The subject is fully discussed in Müller's Physiology, translated by Dr. Baly, vol. 1, pp. 63-88; first edition.]

heat is indispensably requisite for those chemical processes which are the necessary consequences of the proper organic development of the cells of all tissues, and of their catalytic influence on the nutrient fluid, the plasma of the blood: The animal heat is therefore to be regarded as the product of those vital functions, for the due exercise of which it is essentially requisite. The organism is thus protected against the innumerable disturbing forces under which it would otherwise succumb, in consequence of the varying temperature of the external world. The development of heat, therefore, decreases with the diminution of the vital powers, with the retarded circulation of the blood, with checked nutrition, and with imperfect metamorphosis, while all the phenomena of inanition, perfect destruction of power, and finally an asphyxiated condition, are the consequences.

As this cellular action, which is collectively exhibited in the metamorphosis of the animal organism, may be regarded as purely chemical, so the heat that is engendered thereby may be considered as a consequence of these chemical processes, and therefore all those functions of the organism which are necessary for the preservation of life, contribute directly or indirectly to the production of animal heat, which must be regarded as developed at every point at which metamorphosis is occurring, and therefore not merely in the lungs, but in the whole peripheral system. The absorption of oxygen, and its combination with the carbon of animal matter, not only in the lungs, but in the whole body, must, on that account, be regarded as the principal source of heat. In addition to the oxygen required for the formation of the carbonic acid, a certain amount is absorbed, which probably enters in combination with hydrogen, or with binary or ternary radicals of carbon and hydrogen, of carbon and nitrogen, or of carbon, hydrogen, and nitrogen, and in this manner, doubtless, contributes somewhat to the general production of heat.

The theory of animal heat affords a simple explanation of many well-known phenomena, as, for instance, of the slight independent warmth of the foetus, when removed from the uterus (as shown by Autenrieth and Schultz,¹) and of those young animals that are born in an imperfectly developed condition.

The low temperature of persons with *morbus cœruleus*, in whom the metamorphosis of the blood is always imperfect, and the corresponding phenomena that are presented by aged, debilitated, sick persons, and those in whom (according to Edwards) a small quantity of blood circulates torpidly; as well as the increased temperature in inflammatory diseases when the blood circulates more rapidly than usual, and the metamorphosis is more rapid, are other illustrations of the same principle.

The phenomena observed in hibernating animals are strongly corroborative of the mutual dependence of the animal heat and of

¹ *Experimenta circa calorem foetus et sanguinem.* Tub. 1799.

metamorphosis, and also of the intimate connexion of the former with the processes of respiration and circulation.

The observations of Pallas, Spallanzani, Mangili, Saisy, Czermack, and Berthold show that hibernation is prevented by a temperature of from 50° to 80°, whilst it is induced in those animals that are subject to it, even in summer, by means of artificial cold: other observers, however, maintain, that there is a periodical deficiency of vital energy at the usual hibernating season. During this peculiar state the respiration becomes slow, and may even cease altogether; the circulation is likewise almost stopped, for Saisy found that the capillaries of the external parts of the body were nearly empty, while the larger vessels were only half filled, and the undulatory motion of the blood was observable only in the principal trunks of the thorax and abdomen. He likewise found that the blood did not contain the usual amount of fibrin and albumen at this period, and that the bile had a peculiarly sweet taste.

The production of heat is also dependent on the mass of the blood-corpuscles, and on the rapidity of the circulation,—a view that perfectly accords with the preceding statement, for the corpuscles are (as we shall presently show) undergoing a constant metamorphosis, which may be regarded as an evidence of the vitality of the blood, and which is intimately connected with the respiratory process.

When there is a paucity of corpuscles, the necessity for the absorption of oxygen is diminished in a corresponding ratio, the circulation becomes slower, and there is less heat developed than in the normal state: on the other hand, blood with an excess of corpuscles, but which is circulated slowly, develops less heat than blood which contains a smaller proportion of corpuscles, but which is more rapidly circulated, for more oxygen may be consumed in the latter than in the former case.

The following table, drawn up from the researches of Dumas and Prevost, and amplified by my own observations, affords some interesting data on this point:

Animal.	Blood-cor-puscles.	Mean tem-perature.	Pulse.	Respira-tion.
Pigeon	- . .	15·57	107·6	138 34
Common hen	- . .	15·71	108·7	140 30
Duck	- . .	15·01	108·5	110 21
Raven	- . .	14·66	108·5	110 21
Heron	- . .	13·96	111·2	200 22
Ape (<i>Simia Callitricha</i>)	- 14·61	95·9	90	30
Man	- . .	12·92	98·6	72 18
Guinea-pig	- . .	12·80	100·4	140 36
Dog	- . .	12·38	99·4	90 26
Cat	- . .	12·04	101·3	100 24
Goat	- . .	10·20	102·5	84 24
Hare	- . .	9·38	100·4	120 36
Horse	- . .	9·20	98·2	56 16
Sheep	- . .	9·20	100·4	
Ox	- . .	10·50	99·5	38
Carp	- . .	2·10	51·1 to 51·4	20
Tench	- . .	1·40	52·8 to 51·4	
Green toad	- . .	2·90	51·8 to 51·4	77

The metamorphosis of the blood, and the general change of matter, lead to still another secondary source of animal heat. It has been shown by Pouillet¹ that all solid bodies, organic and inorganic, undergo an elevation of temperature when moistened with different fluids. In organic substances it may amount to from 11° to 18°. Since the act of metamorphosis is always effected through humid membranes, this source of heat must be regarded as of great importance, even if it be not actually identical with the catalytic metamorphosis of the cells themselves.

Becquerel and Breschet² have observed, by means of a thermo-electric multiplier, that each contraction of a muscle is accompanied by an increase of temperature, amounting to from 1°·8 to 2°·6, the increased temperature that succeeds violent exercise may probably be in part accounted for by this means.

Metamorphosis of the blood in the nutrition of the organism.

The conveyance of nutriment to the various parts of the organism is one of the most important functions of the blood; and in order to discharge it efficiently, the blood must itself receive a constant supply of proper material.

Regarding the blood physically, as composed of corpuscles and plasma, it is only from the latter that the organs can directly obtain nourishment. This plasma is, however, a very complicated fluid; its principal constituents are albumen, fibrin, fatty compounds, salts, extractive matters, and a peculiar colouring matter, haemaphæin. The question now arises, Are all these constituents, or only some of them, employed in nutrition? Our analysis of urine, sweat, and mucus show that these secretions and excretions carry off, in addition to certain peculiar matters, the same pigment, the same salts, and the same (or similar) extractive matters as are contained in the plasma; hence we may infer that those substances which are removed from the body are effete products of the metamorphosis, and that they are not suited for nutriment, at any rate in the form in which they occur. Neither albumen, fibrin, nor fat³ is found in urine, sweat, or mucus, and the presence of either albumen or fat is always regarded as a symptom of a morbid state. This fact tends to support the opinion that albumen, fibrin, and fat are the substances which are employed in the nutrition of the peripheral system.

The blood, in its passage through the capillary network, permeates all organs and tissues, and their cells take up from the plasma those substances which they require for nutrition, and restore to it those

¹ Annales de Chemie et de Physique, vol. 20, p. 141.

² Annal. des Scien. Nat. 1835.

³ The fat that is occasionally to be detected in the sweat does not arise from the true perspiration, but from the sebaceous glands of the skin. Perfectly normal mucus, such as occurs in some quantity in healthy urine, contains neither albumen nor fat. Pulmonary mucus and the saliva discharged with it often contain a little fat and albumen, but, in all probability, they belong to the saliva only, a fluid not intended to be excreted.

which have become effete, and are no longer adapted for the process of nutrition. We may conclude that the act of nutrition is effected by the sole influence of a vital power inherent in the cells, and that the plasma is entirely passive. If the various tissues of the animal body, different as they are in their chemical constitution, obtain their nourishment from the protein- and fat-compounds of the plasma (which contains the elements of the cells, but not the different cellular substances themselves,) it is clear that the cells and tissues must produce a metamorphic effect on that portion of the nutriment which is homologous with themselves. Their catalytic, or as Schwann¹ in his theory of cells, terms it, their metabolic power, evolves from the plasma the materials that serve for the nutrition of the cells. The plasma is here the cytoplasm, the catalytic or metabolic force lies in the cells and tissues. But although the plasma acts only passively in this nutritive process, we cannot deny it a peculiar vital power. This is first manifested in the formation of the cytoplasm, for the force that creates these forms cannot be regarded as independent of the plasma. If the nucleus is formed by the solidification of fibrin in the plasma, which from the similarity of their constitution is probable, its formation must be regarded as the result of a purely plastic force in the liquor sanguinis. If, however, all the different portions of the body,—the muscles, bones, cartilages, horny matter, serous membranes, sinews, neurilema, brain, &c.,—are nourished and formed by the protein- and fat-compounds of the plasma, we must arrange these compounds into those which *are*, and those which *are not*, homologous to the tissues. Neither albumen, fibrin, nor fat can belong to the second division, since the tissues are formed from these substances.

I have already mentioned, that those constituents of the plasma, that are excreted in the urine and the sweat, cannot reasonably be considered as any longer nutritious, for it would be at variance with our ideas of a consistent organization to suppose that substances which could be subservient to the preservation of the body should be removed from it; it would be just as irrational to conceive that they were conveyed into the body in order to circulate therein, with the nutriment, with no definite object; it only remains then for us to conclude that they are formed in the body, and in that case they can only be regarded as products of metamorphosis. The most important constituents of the secretions and excretions separated from the blood are urea, uric acid, bilin, haemaphæin, biliphæin, extractive matters, lactic acid, salts, and mucus. Mucus must not, however, be regarded as a genuine excretion, for it plays an important part in the animal organism, and its removal is not a matter of vital necessity, but the urea, uric acid, and bilin are chemical combinations which, in a healthy condition of the system, are removed by certain organs in a fixed quantity, but which are not met with in the blood itself: and

¹ Mikroskopische Untersuchungen, p. 391 and 234.

indeed, it is difficult to understand how these products of the metamorphosis of the plasma (constant in their amount, and determinate in their composition) are produced in the formation of tissues, which present entirely different chemical characters, and which are frequently developed in very changeable proportions. It seems more rational to conceive that the urea, uric acid, and bilin are products of the metamorphosis of a substance of a fixed chemical composition, which, by the simplicity and uniformity of the changes to which it is subjected, gives origin to the formation of these products of decomposition. We shall revert to this subject in our observations on the metamorphosis of the blood-corpuscles, and on the manner in which the production of haemaphæsin may be explained.

There still remain for our consideration the extractive matters, the lactic acid of the urine, and the salts: all these substances occur in no inconsiderable quantity in the blood, and their formation during the act of nutrition of the various tissues is consequently very probable. If the various tissues are formed from the plasma of the blood, and if, as is probably the case, their formation is accompanied by the absorption of oxygen and the liberation of carbon, the resulting products may be extremely various: indeed there are so many different forms of extractive matter, of the true nature of which we are still ignorant, that we are justified in the conclusion, that they undergo very complicated transformations during the nutrition of the tissues.

While all the tissues may be considered as albuminous, gelatinous, osseous, horny, or fatty, it must be remembered that the various fats differ materially in their constitution, and that there are similar differences amongst the albuminous tissues. If we regard the extractive matters as the products of the nutrition and waste of the different tissues, the variety in which they exhibit themselves is not at variance with the conceptions we are led to form respecting the nature of metamorphosis. Another circumstance in support of this view is, that the formation of similar matters is observed in the vegetable kingdom, where there is a vital, reciprocal action between the cells and the nutriment, combined either with the production of lactic, or of some allied acid. Although these extractive matters are, without doubt, entirely different from those that occur in the animal body, they correspond in many of their physical and chemical properties: both are incapable of being exhibited in a crystalline form, they dissolve readily in water and partially in alcohol, they are precipitated by many of the metallic oxides, and it is a matter of extreme difficulty to obtain them in a state of purity in consequence of their tendency to undergo transformation and to become chemically changed.

Until the extractive matters of the animal body have been accurately analyzed, and the composition of the various tissues has been determined, it will be impossible to obtain a rational insight into the nature of these changes.

It appears from the statements of Berzelius, as well as from my

own investigations, that some of the extractive matters which occur in the blood and in the flesh are also met with in the urine. It still remains to be decided whether all the extractive matters of the flesh pass unchanged into the blood and are thrown off by the urine, or whether they become changed in their passage; or, lastly, whether they are not partially metamorphosed in certain organs, and again rendered fit to serve the purposes of nutrition. When we consider the wisdom that is universally obvious in the economy of the animal body, it seems probable that the last is the most correct view, and it is by no means improbable that the gelatinous tissues are sustained by a cytoplasm, allied to the extractive matters. The fact that some of the extractive matters of flesh are not only strengthening but very digestible, renders it more than probable that some of the matters of this class serve as nourishment; while others, incompatible with the purposes of nutrition, are excreted.

The plasma of the blood contains salts, some of which are peculiar to that fluid, and are transmitted from thence into the secretions and excretions, while others (especially the phosphates of lime and magnesia, fluoride of calcium, together with small quantities of the sulphates and carbonates of soda and lime), occur in the bones as actual constituents of the body. The latter are conveyed into the body with the food, partly, in the state of phosphates, &c., while their formation is also in part due to the production of phosphoric and sulphuric acids by oxydation of the phosphorus and sulphur which occur in the protein-compounds, and the subsequent combination of those acids with bases. These salts are again found in the urine, for they are removed by the blood during the metamorphosis of the bones, and are excreted by the kidneys. In the present state of our chemical knowledge, it is impossible to assign with certainty any definite function, to the large quantity of salts, which enters the blood, but is not transferred into any of the solid textures of the body. Hewson suggested that the object of the saline constituents of the serum was to enable the blood-corpuscles to retain their discoid form. Albumen, without salts, has as little power as pure water in hindering the solution of the blood-corpuscles. Hewson's view seems to be supported by the facts, that the alkaline salts which occur in only a very slight proportion in solid textures, are found in a very large quantity in the blood; and further, that when water is mixed with blood, by injection into a vein, in a sufficiently large quantity to dissolve or modify the form of the corpuscles, a fatal result ensues. As these salts are continuously introduced into the blood with the food, a corresponding amount must be removed by the excretions. The salts have, however, other functions than that assigned to them by Hewson. The blood, as is well known, has always an alkaline reaction, and it might therefore be supposed that if a large quantity of an acid were taken, the reaction of the blood would be neutralized. This is, however, by no means the case, partly because only a certain quantity of the acid enters the blood, the remainder being carried off

by the intestinal canal, and partly because the portion that does enter the circulating fluid is at once removed by the kidneys. Thus all the mineral acids may be detected in the urine after their administration; the vegetable acids appear, however, to undergo a partial change, at least Wöhler found that neutral potash, or soda salts, formed by a vegetable acid, were decomposed in the organism, and that the bases were removed by the urine in the form of carbonates. We thus see that the existence of basic salts in the blood is indispensably necessary; and as neutral or acid salts are usually contained in food, it is clear that they must undergo such a change in the body as to permit of the removal of the acids by the urine while the bases are retained.

There is every reason to suppose that the basic salts of potash and soda in the blood serve for the purpose of combining with the lactic, fatty, uric, and probably carbonic acids that are continually secreted during metamorphosis.

The salts of lactic and uric acid are in part excreted in that form; and in part, as has been remarked, are decomposed, so that the free acids are separated by the kidneys, while the bases are retained. The salts of the fatty acids appear to be secreted only in the liver. Whether chloride of sodium, which appears to be requisite for all the mammalia, serves merely for the purpose of preventing the solution of the blood-corpuscles, or whether it does not, like some other salts, act as a stimulant on the nerves, and in that manner influence the composition of the blood, is a question not easily answered.

Active Metamorphosis of the blood.

As the plasma is subjected to a continuous change in the peripheral system during the nutrition of the tissues, it becomes a matter of necessity that it should also receive a continuous supply. This is afforded to it by the chyle, a fluid generally only poorly supplied with blood-corpuscles, but abounding (at least at certain times) in lymph- and chyle-corpuscles, and oil-vesicles, and containing some fibrin. The chyle is, therefore, not blood, although closely allied to it; if, however, as is generally believed, the chyle is the only nutriment of the blood, it must ultimately be changed into blood, and this transformation is effected by an increase of the blood-corpuscles, and by a diminution of the lymph-, chyle-, and fat-corpuscles, while the fibrin is not only increased, but becomes more plastic. A change must therefore take place in the blood itself, and this must be not of a passive nature, as during nutrition in the peripheral system, but active; we must assume that there is a formation and development of certain substances in the blood, produced by a certain vital power inherent in this fluid, with the aid of necessary potential forces, as, for instance, of oxygen. This change or metamorphosis represents the real vitality of the blood, and, as far as we at present understand it, we may describe it as a process in which not only blood-corpuscles are formed, (by a consumption of lymph-, chyle-, and fat-globules,) and fibrin is

produced, but further, in which the blood-corpuscles are again consumed; for it is obvious that if there is a continuous process of formation while their total number remains nearly constant, there must be a corresponding consumption of them.

The presence of atmospheric oxygen is indispensably requisite for this active metamorphosis of the blood, and one of the results of this change is an excretion of carbon, which combines with a portion of the absorbed oxygen, so as to develop a certain degree of warmth. The probability that the chemical process, which occurs during nutrition in the peripheral system by means of the plasma, involves the absorption of oxygen, has been already noticed. The importance of the presence of oxygen, for the perfect metamorphosis of the blood, indeed for life itself, is sufficiently obvious from the circumstance that the cessation of the respiratory process is followed by immediate death.

Although the respiratory process is as necessary for the active metamorphosis of the blood as for the production of animal heat, yet neither of these processes is to be referred to the lungs alone, but to the whole peripheral system. If it were otherwise, the temperature of the lungs would be much higher than it actually is; whereas, in reality, the excess of temperature of those organs is very slight, and may probably be sufficiently accounted for by the more energetic action of the atmospheric oxygen on the mass of the blood in these organs than in other parts of the body.

I cannot give any description of the manner in which the blood-corpuscles are formed from the consumption of lymph-, chyle-, and fat-corpuscles. Physiologists suppose that a capsule, which at first is very thin, but subsequently becomes thicker and thicker, is developed around the lymph-corpuscle: this capsule is filled with haemato-globulin, which at first is comparatively colourless, but subsequently assumes a vivid red tint. We are perfectly unable to state where the first haemato-globulin is formed, but there is no doubt that the respiratory process is essential to its production.

Schultz and Henle have examined the blood-corpuscles in their various stages of development, and have arrived at very similar conclusions. Schultz¹ observed that the young corpuscles were poorer in colouring matter than the older ones, and that, consequently, the nucleus was much more distinct. The capsule becomes tumid in proportion to the age and development of the blood-corpuscle, whilst the nucleus becomes gradually smaller, and in some cases entirely disappears. Water acts very differently on blood-corpuscles in different stages of development. The young and more delicate blood-corpuscles are quickly and readily dilated by a very small quantity of water; they are soon entirely deprived of their colouring matter, and become perfectly clear and transparent; whilst the older and more developed corpuscles entirely resist the action of the water, or at the most only become rounded, and do not dissolve except on the

¹ Ueber die gehemmte und gesteigerte Auflösung und Ausscheidung der verbrauchten Blutbläschen. Hufeland's Journal, 1838.

addition of a large quantity of water. They remarked at the same time that the corpuscles most abundant in colouring matter frequently presented a minute nucleus up to their final disappearance; while many of the most highly developed ones gave no indications whatever of a nucleus.

That a metamorphosis of the blood-corpuscles does occur cannot be for a moment doubted, but with respect to the peculiar circumstances under which it is conducted, and to the products that are then formed, we know scarcely any thing: all that we have been able to ascertain with any degree of certainty is, that oxygen is absorbed, and carbon given off during the process; and the following facts justify us in this conclusion:

a. Dark blood, both within the system and out of it, assumes a lively reddish tint on being brought in contact with oxygen. This change is probably based on a chemical change in the haematin.

b. Blood taken from the body and agitated with oxygen absorbs a certain portion of the gas, while carbonic acid is formed. The mere serum, however, which contains no blood-corpuscles, absorbs only a very little oxygen, and develops carbonic acid in a corresponding ratio.

c. The consumption of oxygen and the formation of carbonic acid stand in a direct ratio with the amount of blood-corpuscles and with the number of respirations in a given period.

Hence, it is obvious that the oxygen taken up by the blood during the respiratory process, is, for the most part, consumed in the metamorphosis of the corpuscles.¹

¹ There are two rival theories respecting the manner in which oxygen is taken up by the blood and conveyed to the peripheral system. Liebig maintains that this is effected solely by the iron in the corpuscles, while Mulder refers it entirely to the oxidation of protein-compounds. Liebig asserts that the corpuscles of arterial blood contain peroxide of iron; that, in their passage through the capillaries, they lose a portion of their oxygen and combine with carbonic acid, so that, in the venous system, they no longer contain peroxide, but carbonate of the protoxide of iron. When they reach the lungs, an exchange takes place between the carbonic acid of the blood and the oxygen of the atmosphere. Mulder, on the other hand, denies that the blood-corpuscles are conveyors of oxygen, and that iron is oxidized during respiration, as assumed by Liebig, and he founds his conclusions on the following grounds:

a. The iron is so intimately connected with the other elements of haematin that it cannot be removed, even by long digestion of this constituent in dilute hydrochloric or sulphuric acid. (Vide supra, p. 41.) Consequently it is highly improbable that it should be oxidized in the lungs. Liebig, indeed, observes, that dilute acids remove iron from dried blood, but Mulder gets over this difficulty by showing that other constituents of the blood, besides the colouring matter contain this metal, apparently in an oxidized state.

b. If, as Liebig asserts, peroxide of iron exists in arterial, and carbonate of protoxide of iron in venous blood, almost any dilute acid would be capable of extracting the oxide, which we have shown not to be the case.

y. Assuming, with Liebig, that the iron exists in arterial blood as a peroxide, the organic part of haematin would be different; instead of being $C_{44}H_{52}N_4O_6$, it would be $2(C_4H_{52}N_4O_6 \cdot Fe) = Fe_2O_3$, or $2(C_4H_{52}N_4O_6 \cdot)$.

d. The probability of its existence in a metallic state has been already shown. (Vide supra, p. 42.)

e. The amount of haematin in the whole mass of the blood is far too inconsiderable to carry a due supply of oxygen to the whole system.

Mulder's theory has been alluded to in an early part of this work. (Vide supra, p. 12, note.) We shall have occasion to notice it at some length in our observations on the differences between arterial and venous blood.]

The development of the blood-corpuscles is doubtless conducted on the same principle as that of other cells; i. e. the blood-corpuscles exert a transforming influence on the surrounding plasma; they select from it the materials requisite for their development, and reject the non-homologous products that are formed in it. Amongst the matters that are taken up there must be always free oxygen.

During the latter stages of development of the blood-corpuscles up to their final solution, they must undergo so thorough a change as to leave no remains of their principal constituents, the haemoglobin, the nuclei, and the capsules, for not a trace of these substances is found either in the plasma or in any of the secreted or excreted fluids, in which we should naturally expect to find them. It is altogether impossible to state how this change takes place; this, however, is evident, that if the metamorphosis of the blood-corpuscles terminates in their perfect solution, both the capsule and the nucleus must be entirely dissolved, and neither haematin nor globulin can be contained in it at the moment of solution. What the products of this change actually are is very difficult to determine with any degree of certainty.

Transitory combinations with a brief existence may be produced, or compounds may be formed, which undergo a further decomposition in certain organs. It is very probable that substances closely resembling the extractive matters are formed in the metamorphosis of the blood corpuscles, by the decomposition of which, urea or uric acid are produced, so that by the influence of a certain organ (the kidney) the compound is separated into those substances, and another form of extractive matter. It may further be presumed that the composition of haemaphæin is such as to include the constituents of biliphæin, and that the hepatic cells possess the power of secreting the biliphæin from it.

Combinations may likewise be formed of which we know actually nothing; for the blood has not yet been sufficiently examined. These points need not engross our consideration at present; and I will only remark, that in my attempt to prove that the fibrin and haemaphæin of the plasma, the urea, uric acid, bilin and its acids, the biliphæin, and certain acid fats, are products of the metamorphosis of the blood-corpuscles, I by no means conclude that they are the *only* products; in fact, I freely grant my assent to the possibility of many others.

The blood contains a certain amount of fibrin, varying from .2 to .9, or according to Andral even to 1.0%, which on whipping is separated in thickish, globular, elastic, stringy masses; the chyle appears from my analyses to contain not more than from .02 to .04% of fibrin, which, in consequence of its slight tenacity separates on whipping into loose and globular, or else into flocculent mucous masses. Fibrin is therefore obviously formed in the active metamorphosis of the blood; and that portion which pre-exists in the chyle is modified and rendered more plastic. It is a well-known fact that the respiratory

process not only increases the plasticity of fibrin in the blood, but also its quantity, and that on the other hand the amount of fibrin diminishes in blood which is not efficiently brought in contact with oxygen. As the blood-corpuses principally consume oxygen during their change, it appears very probable that the fibrin is produced during this process.

This view is elucidated, and I may say confirmed, by my analyses of the blood, in which it appears that with very few exceptions, the amount of fibrin always varies inversely with the mass of the blood-corpuses, or, in other words, that the more corpuses there are, the less in quantity is the fibrin, and *vice versa*. This fact is readily explained by the adoption of the view that fibrin is formed from the blood-corpuses; for it is obvious that the quantity of fibrin in the plasma must increase during an extraordinary consumption of the corpuses.

Let us now inquire which of the constituents of the blood-corpuses has been employed in the production of that most essential ingredient of the plasma, the fibrin? It can hardly be the globulin, for that forms from 4 to 10% of the blood, and, being a protein-compound, is so intimately connected in its chemical relations to fibrin, that if we were to suppose that it were converted into fibrin, we should expect to meet with a much greater quantity of this latter constituent in the blood than we find actually existing; still less can it be the haematin; indeed, the use of this appears to be *to facilitate and to maintain the independent metamorphosis of the blood-corpuses, through its energetic capacity for the absorption of oxygen, and through its own metamorphosis*, instead of forming a product for the further nutrition of the plasma. The capsules and the nuclei still remain for consideration. Of the former we know very little, but the latter actually possess chemical characters which approximate them to fibrin, so that there is no impediment to the supposition that this important constituent of the blood is formed from the nuclei by a metamorphic process, accompanied probably by the absorption of oxygen and the separation of carbon.

The nuclei may be distinctly seen in young blood-corpuses, but in the process of development they become smaller, and, according to Schultz and Henle, as the final solution of the blood-corpuses approaches, they altogether disappear; hence the metamorphosis of the nuclei is by no means sudden, but progresses with the development of the blood-corpuses.

Burdach,¹ R. Wagner,² and Valentin³ are of opinion, that as long as the blood-corpuses circulate in the living body, they possess no nucleus, and that this is only formed at the instant that the blood-corpuse is removed from the circulation. R. Wagner found that nuclei were formed by the mere contact of the blood-corpuses

¹ Physiologie, vol. 4, pp. 27 and 94.

² Beiträge zur vergleichenden Physiologie des Blutes, 1838, p. 14.

³ Handbuch der Entwicklungsgeschichte des Menschen, p. 296.

with atmospheric air. This is a further point of analogy between the nuclei and the fibrin of the plasma; and if we could only succeed in observing the unequivocal reappearance of a nucleus in a blood-corpuscle removed from the body, and in which, on account of its advanced development, the nucleus had undergone solution, we might then, in my opinion, consider that the change of the nuclei into fibrin was sufficiently established, especially when we reflect that no other constituent of the blood possesses the extremely characteristic property of being retained in solution in living blood, and of separating into an insoluble mass as soon as the vitality of the fluid is destroyed.

If we assume that the fibrin is formed in this manner, it follows that the amount of fibrin must always stand in an inverse ratio to that of the blood-corpuscles; and this is in reality the case,—that whenever the activity of the metamorphosis is increased, the amount of fibrin must likewise increase; and further, that whenever the blood is hindered in its circulation, or its supply of oxygen is stopped or lessened, the amount of fibrin must diminish. All these consequences really take place. Blood that stagnates in the vessels loses fibrin, for it is consumed, while no fresh supply can be formed. Menstrual blood, and the blood in melæna contain no fibrin;¹ and I shall subsequently refer to other similar cases.

Let us now proceed with the metamorphosis of the blood-corpuscles; the next question for consideration is this: *What changes do the hæmatin and globulin undergo?* It has been already shown that both these substances must undergo an entire change during the period of development of the blood-corpuscles, that terminates in their consumption or solution. The plasma contains a peculiar colouring matter, hæmaphæin, to which it owes its yellowish colour,² and which cannot accumulate in it beyond a certain amount, because it is continuously removed by the kidneys; it is, in fact, this constituent that gives the yellow or yellowish-brown tint to the urine.

It can hardly be doubted that the hæmaphæin is a product of the metamorphosis of the hæmatin; especially, if it can be proved that it is formed solely from the blood-corpuscles, and that it is contained in them to a large amount. We can obtain from the serum only slight traces of hæmaphæin, but the clot yields a considerable amount of colouring matter, which must be therefore contained in the blood-corpuscles. The hæmaphæin is formed from the hæmatin during the development of the blood-corpuscles, and the change is probably accompanied by an absorption of oxygen and a separation of carbon; the youngest blood-corpuscles must consequently contain less hæ-

¹ [That the menstrual discharge does *occasionally* contain fibrin will be shown in a future part of this work.]

² When the serum, after the separation of the clot, is of a reddish tint, which is not unfrequently the case, blood-corpuscles are suspended in it. In uterus the serum is often of a brownish red colour, in consequence of the presence of biliphein; in this case the colour rapidly changes into a green, on the addition of nitric acid.

maphæin than those that are older; and when the act of development terminates in their solution, they no longer possess any hæmatin, but only hæmaphæin. In a normal state, the consumption and production of the blood-corpuscles must be nearly balanced, and consequently the proportion of the hæmatin to the hæmaphæin will remain tolerably constant; when the metamorphosis of the blood is accelerated (i. e. when the circulation is quickened, and the mutual action between the blood and oxygen is increased) more blood-corpuscles will be consumed in a given time than in the normal state, and the consumption will especially include the older ones which abound in colouring matter, and which in their development are approximating to the stage of solution.

In these cases there is, therefore, not merely a diminution of the quantity of the blood-corpuscles, but likewise of the colouring matter contained therein, since the corpuscles that remain are young and deficient in colouring matter, containing, in addition to hæmatin, only a very small quantity of hæmaphæin. If the circulation of the blood is impeded in any part of the body, and it is prevented from receiving its due supply of oxygen, the metamorphosis will likewise be impeded and rendered imperfect; the matured blood-corpuscles which are approaching the stage of solution will not be dissolved, and there will consequently be an accumulation of colouring matter, especially of hæmaphæin, which is the most abundant pigment in the matured corpuscles.

All these appearances are actually observed. I shall be able to demonstrate that, in inflammatory affections, (when the metamorphosis of the blood is excited to increased activity in consequence of the accelerated circulation and the increased mutual action of the blood and oxygen,) there is only a small amount of colouring matter present in the blood, and that, in all probability, hæmaphæin constitutes but a minute portion of the little that does exist; while, on the other hand, in blood which is retained in the body without being submitted to the due action of oxygen, in which the perfect metamorphosis is checked, and the corpuscles are not dissolved, as in melæna and in morbus maculosus, there is a great excess of hæmaphæin. The colouring matter may also accumulate when organs that take an active part in the metamorphosis of the blood are affected, as I have observed in morbus Brightii.

I shall now proceed to show that it is much more probable that such substances as urea, uric acid, and bilin, which are definite compounds secreted in a nearly constant ratio by peculiar organs, should be products of the active metamorphosis of the blood-corpuscles, than that they should be formed during the metamorphosis of the plasma in connexion with the process of nutrition.

It is but reasonable to infer that such substances as urea, uric acid, and bilin, which are separated in large quantity by the kidneys and liver from the blood, should be products of the metamorphosis of a substance of an invariably uniform composition. In every class of

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animals, in the most varied forms of existence, under the most opposite kinds of food, we find that the bile is a secretion of the liver; whilst amongst all the higher classes of animals and many of the lower, urea and uric acid, or one of the two, occur as a constant secretion of the kidney.¹ It seems opposed to all reason to imagine that in animals as different in structure as they are opposite in their habits of life, and under every possible variation of circumstances, these fixed and definite compounds should be products of the metamorphosis of the plasma during the nutrition of every form of tissue. It is, however, easy to conceive that the corpuscles which, although different in their form, are similar, if not identical, in their chemical constitution, in the blood of all these animals, should, under similar conditions, yield similar products as the result of their metamorphosis, and that these products should take the form of urea, uric acid, and bilin. This consideration alone is deserving of much weight in support of the view that I am now advocating. If the urea, uric acid, and bilin were formed in accordance with the other hypothesis, their production would be increased, diminished, or stopped, according as nutrition was proceeding favourably, was deficient, or was entirely checked, as happens in certain disorders. But it is well known that the production of these substances is by no means dependent on such circumstances. The secretion of urea, uric acid, and bile proceeds, both in man and animals, when the tissues are gradually wasting from disease, and when their nutrition is utterly suspended; they are separated long after the body has ceased to take any food whatever, in fact, as long as respiration and even life itself remains, the only necessary condition being the healthy state of the secreting organs. I have had several opportunities of examining the urine during inflammatory diseases, both before and during, or shortly after the height of the attack, and have found that, in the latter case, there was always a greater amount of urea than in the former. This is easily explained by the consideration that the active metamorphosis of the blood-corpuscles is accelerated by an excited inflammatory state, and that, consequently, a larger number of the corpuscles is consumed during a given time, than in the ordinary condition of the system.

My analyses of the blood are even more confirmatory than any of the preceding statements, of the production of these substances during the active metamorphosis of the corpuscles.

I analyzed the blood of the aorta and vena renalis of one animal, and the blood of the vena portarum and vena hepatica of another animal, with the following results:²

¹ Müller's Handbuch der Physiologie, vol. 1, pp. 515 and 588.

² In the first analysis, the venous blood from both the renal veins was collected. The amount, although small, was sufficient for the required purpose. Professor Gurit, of our veterinary school, had the kindness to obtain the blood for me.

1.	a. Blood of aorta, in 1000 parts.	b. Blood of vena renalis, in 1000 parts.
Water - -	790-000	778-000
Solid constituents - -	210-000	222-000
Fibrin - -	8-200	? ¹
Albumen - -	90-300	99-230
2.	a. Blood of vena portarum.	b. Blood of vena hepatica.
Water - -	738-000	725-000
Solid constituents - -	262-000	275-000
Fibrin - -	3-500	2-500
Fat - -	1-968	1-560
Albumen - -	114-636	130-000
Globulin - -	116-358	112-580
Hæmatin - -	4-920	4-420
Hæmaphæin - -	1-467	1-040
Extractive matter - -	16-236	17-160

Here we observe that the arterial blood contains more water than the blood of the renal vein, and that the blood of the vena portarum contains more than that of the vena hepatica; the arterial blood and the blood of the vena portarum contain a larger amount of fibrin than the blood from the renal and hepatic veins respectively. The blood of the renal vein contains more albumen and fewer blood-corpuscles than arterial blood, and a similar relation holds good between the blood of the hepatic vein and of the vena portarum. Passing over all other points of difference, the results at which we have already arrived afford an *a priori* argument for, and a confirmation of, my theory respecting the formation of urea, uric acid, and bile, from the corpuscles during the active metamorphosis of the blood.

Since the kidneys and the liver secrete fluids from the blood of less specific gravity than the blood itself, it is clear that in its passage through these organs it must become richer in solid constituents than before it entered them; moreover, as in its circulation through these organs it meets with no free oxygen, it must be poorer in fibrin when it leaves them than on its entrance.

The change that the blood undergoes in these organs, is, however, by no means so simple as it might appear to be, and as, in fact, these analyses might lead us to conceive. There result from it the products of the metamorphosis of the corpuscles, or of the compounds that are formed from them, as well as of the plasma, during the nutrition of these organs. The excess of albumen in the blood of the renal and hepatic veins is clearly opposed to the view that the urea and bilin are formed from the plasma.

It is sufficiently established that the renal cells possess the power of removing an excess of salts and water from the blood, in the same manner as the hepatic cells separate fat.

I beg expressly to repeat, that I do not regard the urea, uric acid, and bilin, as the only substances that are formed, besides fibrin and hæmaphæin, during the active metamorphosis of the blood-corpuscles;

¹ The whole amount of blood from both renal veins did not exceed sixteen grains, a quantity not sufficiently large to admit of the determination of the fibrin by whipping. I employed it in determining the ratio of the albumen to the dried residue, and found that while the aortic blood contained 43, the blood of the renal veins contained 44 $\frac{7}{8}$ of albumen.

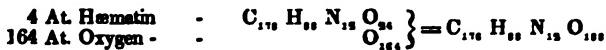
on the contrary, I am of opinion that other substances are likewise produced, regarding the formation of which we might speak with greater certainty if almost every thing regarding them were not based on mere conjectures. It is, for instance, very probable that a portion of the globulin is converted into albumen, which, since both substances are protein-compounds, might happen in two ways, either by a portion of the phosphorus, or sulphur, being oxydized, if globulin contain more of those elements than albumen; or if, on the other hand, it contain less, by the globulin dividing into, for instance, one-half or one-third of a protein-compound with all the phosphorus and sulphur, and into one-half or two-thirds of a protein-compound devoid of phosphorus and sulphur, which then undergoes further metamorphosis. The fat, which is more abundant in the blood-corpuscles than in the serum, must likewise undergo a change. The fat of the serum appears to be softer than that of the corpuscles, while that of the fibrin is firm and white. In all of them there is cholesterin, margaric and oleic acids. Berzelius could detect no phosphorus in the fat of fibrin; neither did Lecanu find any in the fat of the serum. The fat containing phosphorus, which Boudet found in the blood, must belong to the corpuscles. We cannot form any very clear idea of the manner in which these metamorphoses are conducted; it is, however, probable that the phosphorised fats are conducted to the brain. Since the fats that are taken as food consist, for the most part, of stearin, margarin, and olein, it would appear as if fatty acids were formed from them by a process of oxydation during the succeeding formation of blood-corpuscles, and the consumption of lymph-, chyle-, and oil-globules.

The elementary composition of many of the substances that are formed from the blood, and of some that occur in it, are known to us, but of the greater number of the matters that are produced during its metamorphosis, particularly of the extractive matters, we are entirely ignorant.

The extremely high atomic numbers of many of these substances, as, for instance, of the protein-compounds, renders it very probable that each atom is decomposed into various new atoms of less atomic weight. We are, however, at present entirely deficient in many of the requisite-data, in our knowledge regarding the connecting links, as, for instance, of the composition of the extractive matters, of the different tissues, &c., without which even a superficial insight into the nature of the metamorphosis of the blood cannot possibly be obtained.

With the scanty materials in our possession, we may nevertheless attempt an ideal sketch of the metamorphic action that goes on in the blood, the conditions being that there is an absorption of oxygen, and that carbon is given off; it will, at any rate, afford an illustration of the facility with which such equations may be deduced, and of the slight degree of confidence that should be placed on their interpretation, unless they are tested by established facts.

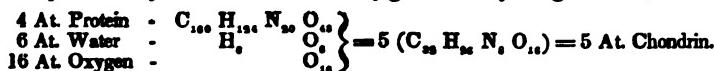
We may, for instance, suppose that 4 equiv. of the organic portion of haematin ($C_{44} H_{58} N_4 O_6$) by the absorption of oxygen, will be decomposed into choleic acid, uric acid, urea, and carbonic acid. Thus—



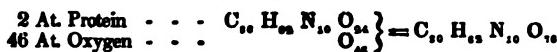
Likewise,



We can also show how chondrin may be supposed to be formed from protein by the addition of oxygen and hydrogen: for,



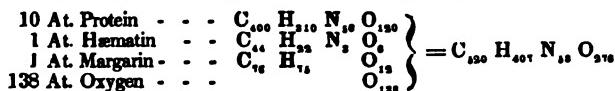
We may, in a similar manner, conceive that glutin, urea, and lactic acid are formed from protein by the absorption of oxygen, and the liberation of carbonic acid; for,



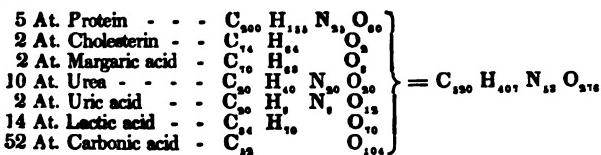
Likewise,



If we conceive that the blood-corpuscles are formed of globulin (a protein-compound,) haematin, and margarin, they may, by the absorption of oxygen and the development of carbonic acid, be decomposed into many other substances, as, for instance, into protein, cholesterol, margaric acid, urea, uric acid, and lactic acid; for,



Likewise,



Many similar illustrations of possible metamorphic actions might be adduced; but, as they do not contribute to the advancement of chemical science, we shall omit to notice them.

2. Special chemistry of the blood.

Proximate constituents of the blood.

The blood is a fluid of a very complicated nature, and has been proved to include the following constituents in man and in certain mammalia:

Protein-compounds	-	Water. Fibrin. Albumen. Globulin. Hæmatin. Hæmaphæin. Alcohol-extract.
Colouring matters	-	Hæmaphæin. Alcohol-extract.
Extractive matters	-	Spirit-extract. Water-extract. Cholesterin. Serolin.
Fats	- - - - -	Red and white solid fats, containing phosphorus. Margaric acid. Oleic acid. Iron (peroxide.) Albuminate of soda. Phosphates of lime, magnesia, and soda. Sulphate of potash.
Salts	- - - - -	Carbonates of lime, magnesia, and soda. Chlorides of sodium and potassium. Lactate of soda. Oleate and margarate of soda.
Gases	- - - - -	Oxygen. Nitrogen. Carbonic acid. Sulphur. Phosphorus.

Traces of the following substances have also been detected in the blood in certain pathological states of the system:

Sugar.
Urea.
Bilin and its acids. (?)
Biliphein.
Glutin. (?)
Hæmacyanin.
Erythrogen.
Hydrochlorate of ammonia.
Acetate of soda.
Benzoate of soda.
Margarin.
Olein.
Copper.
Manganese.
Silica.

On the methods of analyzing the blood.

Although many of the proximate constituents of the blood may be recognised without difficulty, there are some (especially those which exist in only minute quantity) that cannot be readily detected. An exact quantitative analysis of the blood, including the determination of all the substances in the foregoing table, would, in the present state of chemistry, be almost an impossibility; we must, therefore, content ourselves with the quantitative determination of the *more*

important constituents, and arrange and determine the others, as, for instance, the fats, salts, extractive matters, &c., in groups. For this purpose fresh blood must be used: the clot must be allowed to separate from the serum, and the two (the clot and the serum) must then be analyzed separately.

The following method is given by Berzelius.¹ Two known quantities of blood are taken, one of which is allowed to coagulate spontaneously, while the other is evaporated for the purpose of ascertaining the quantity of water. The clot, when thoroughly separated, is removed from the first of these quantities, cut into pieces, and placed upon an open weighed filter, resting upon several folds of blotting paper; it must then be covered with a similar weighed filter, over which some more blotting paper must be placed, and the whole must be compressed by a stone or other weight. The blotting paper must be changed as long as any moisture is communicated to it, and the clot must be subsequently dried *in vacuo* over sulphuric acid, and carefully weighed. By deducting the known weight of the filters we obtain that of the fibrin and blood-corpuscles.

The dried clot must now be frequently washed with water at from 75° to 85°, until the fibrin is left colourless.

The dried blood which has been used for the purpose of ascertaining the quantity of water must be successively treated with ether, alcohol, and boiling water. The ultimate residue consists of fibrin, blood-corpuscles, and albumen; by deducting the already determined weight of the fibrin and blood-corpuscles, we obtain the weight of the albumen. Ether takes up the fat; alcohol, certain extractive matters, and lactates; boiling water, certain extractive matters, chloride of sodium, &c. The serum (the quantitative relation of which to the clot is known) is gently boiled, by which means the albumen is coagulated, and all moisture is removed by evaporation.

The dried residue is pulverized and treated with boiling water, which leaves albumen and fat unacted upon; the latter of which may be now taken up by ether.

The water dissolves the salts, certain extractive matters, and some fat, or fatty-acid compounds.

The watery solution must now be evaporated, and the residue treated with alcohol, which takes up the chlorides of sodium and potassium, the lactates, extract of flesh, and perhaps some fat, if any happens to be present.

An objection may be raised against this method, that the separation of the blood-corpuscles from the serum is not sufficiently perfect.

The complete removal of the serum is a matter of very considerable difficulty, in consequence of the formation of a dried surface, at those parts of the clot which are in contact with the paper, by which means a check is opposed to the egress of any moisture from the interior portions. Indeed, the moist clot can only be perfectly freed from haemoglobin with difficulty, and with the loss of some

¹ Thierchemie, p. 93.

fibrin; if it were thoroughly dried, the difficulty would be confined to the washing out of the blood-corpuscles. But when fibrin remains for a considerable time in water, a small portion of it is dissolved, and a part of it is transformed into a viscid mass, consisting of very minute microscopic granules, which are not easily washed out. When all the blood-corpuscles are not enclosed by the coagulated fibrin, the serum assumes a reddish tint in consequence of their presence; they must then be taken into estimation with the serum. In most cases, analyses made in this manner would yield too high a number for the blood-corpuscles; in some few cases the assigned number would be too small.

Lecanu's method of analyzing the blood is very similar to that of Berzelius.

Denis¹ adopts a method of analyzing this fluid which involves considerable time and manipulation; and, after all, does not give results of very great accuracy.

Fresh blood is received into two vessels of known capacity, one of which is narrow and high. One portion is used for the determination of the water, the carbonate of soda, and the chlorides of sodium and potassium; the other for the estimation of the other constituents of the blood.

I. The first portion is evaporated to dryness in the water-bath, pulverized in an agate mortar, again heated on the water-bath, and the quantity of evaporated water estimated.

The residue is incinerated, digested in water, and filtered; the filtered solution is evaporated to dryness, and the residue is weighed, dissolved in water, and treated with nitrate of silver; chloride of silver, and oxide of silver (?) are precipitated. This precipitate is dissolved in nitric acid, the solution is evaporated and crystallized; the crystals are dissolved, decomposed, and neutralized by carbonate of soda. The solution which is thus obtained (of nitrate of soda) is filtered, evaporated to dryness, and incinerated with animal charcoal in a platinum crucible. It is then digested in water, and the carbonate of soda ascertained. Upon deducting the weight of the salt from that of the whole ash of the blood, we obtain as a residue the weight of the chlorides of sodium and potassium.

II. The other portion is allowed to stand for twenty-four hours, in order to permit of the thorough separation of the clot from the serum.

The latter is removed with a pipette, and the separation is continued until incipient signs of decay present themselves. The water is removed from the serum, *in vacuo*, at a temperature of from 120° to 140°. The clot is placed in a small bag and washed with water until all the colouring matter is removed. The residue, consisting of fibrin, is then placed in the water that has been used for the washing of the clot. The fibrin is separated by decantation, the solution of colouring matter being carefully poured off. It is then washed

¹ *Recherches Expérimentales sur le Sang humain, considéré à l'état min,* par S. Denis: Paris, 1830, p. 121.

with fresh water. In the separation of the hæmato-globulin from the fibrin, according to this method, about the seventieth part of the clot is lost in the water. The solution of the colouring matter is heated until the coagulation of the hæmato-globulin is effected, which is then separated and freed from moisture by pressure.

The fluids are then evaporated to dryness. We have now four subdivisions:

- a.* The fibrin which still contains fat and cruorin.¹
- b.* Albumen with cruorin, salts, and extractive matter.
- c.* Hæmato-globulin with fat, extractive matter, and salts of iron and the earths.
- d.* The evaporated fluid separated from the hæmato-globulin, containing salts and osmazome.

These four portions are dried, weighed, put into glass flasks, and submitted for some minutes to the action of alcohol of '800—'820, at a temperature of 86°; they are then filtered, and the spirituous solutions united and evaporated. The residue, consisting of extractive matters and salts, must be incinerated, by which means the quantity of extractive matter is determined.

The four portions must now be treated with boiling water, by which cruorin and certain salts are removed.

The portions *a* and *d* are now combined, and the three are treated with boiling alcohol of '800 for the purpose of extracting the fat. The filtered solutions are united and evaporated, and the cholesterol separated by crystallization from the fats which contain phosphorus. The mixed portion of *a* and *d* contains tolerably pure albumen; it is dried, weighed, and incinerated, and the ash is preserved.

The second portion contains fibrin; this likewise is incinerated, and the ash added to the former.

Lastly, the hæmato-globulin is dried, weighed, and incinerated. The collected ashes are analyzed with regard to the proportions of peroxide of iron, phosphates of lime and magnesia, &c.

This method is objectionable, not merely on account of the time and labour required for its various stages, but further, because the whole of the water cannot be estimated by the indicated process. Moreover, the quantity of the hæmatoglobulin which is dependent upon the quantity of blood-corpuscles, will be given in excess, as it is certain that the whole of the serum cannot be separated from the clot, in the manner proposed by Denis. The determination of the fibrin may also be inaccurate in consequence of the continuous treatment of the clot with water, which has the effect of transforming a portion of it (i. e. the fibrin) into minute flocculi or granules which combine with a viscid substance. The estimation of the fat and of the extractive matters is also very inaccurate; the quantity

¹ Denis applies the term *cruorin* to a substance obtained by boiling fibrin and albumen in water. It is soluble in water, insoluble in alcohol and ether, of an agreeable taste, and precipitable by tannic acid. It appears to be produced by the action of the boiling water on fibrin previously affected by long contact with water.

of fat given by Denis in his analyses being much too large, and of extractive matter, too small. Finally, no certain results with respect to the separation of the salts can be obtained by this method. Whatever may be the faults of his process, he is at least deserving of praise for having conducted no less than eighty-three analyses in this laborious manner.

The method that I pursue in the analysis of the blood, if not strictly correct, at least gives results that approximate nearer to the truth than those of Denis. In explaining it, I must enter a little into detail, in order to indicate certain necessary precautions, and to explain on what points it is deficient.

a. I receive two, three, or at the most four ounces of blood, as it flows from the vein, in a thin glass, and stir it,¹ but not violently, till the fibrin separates. If it be stirred too violently, a portion of the fibrin becomes separated in the form of finely-divided scum, which cannot be easily collected. When the blood has completely cooled, it is weighed, together with the rod and glass, in a good balance; it is then poured out, the glass is cleansed and dried, the rod is freed from the adherent fibrin, and is washed and dried: the glass and rod are then weighed, and the quantity of blood determined.

b. Any fibrin that separates in flocculi from the blood must be collected, added to the former, pressed, and placed in water. If the water become strongly coloured, it must be poured off and renewed until the fibrin is found to be colourless, which is usually the case in from 18 to 24 hours. It is almost needless to mention that none of the flocculi of fibrin must be allowed to escape when we pour off the water. The decolorized fibrin is dried, cautiously broken up, pulverized in an evaporating basin, and then submitted to a temperature of 230° until it ceases to lose weight.² It is then weighed. It is again finally triturated, placed in a flask and heated, first with anhydrous alcohol, and then with ether, for the purpose of extracting the whole of the fat. The ether and alcohol must be evaporated in the water bath, and the weight of the fat estimated. The quantity of fibrin and of fat associated with it must then be calculated in regard to the whole quantity of the blood.

c. A quantity varying from 30 to 50 grains of defibrinated blood must be accurately weighed in a small basin, and cautiously heated over the flame of a spirit-lamp. This portion must then be triturated, submitted to the action of the water-bath, pulverized as completely as possible, and the heat continued until it ceases to lose weight.

¹ [A bunch of fine twigs is generally used for this purpose, but the fibrin may be obtained with as much accuracy by shaking the blood in a stoppered bottle containing a few fragments of lead, to which it readily adheres.]

² I may observe that, in my analyses of blood, I always use small porcelain basins, weighing from 200 to 300 grains, and that I pulverize dried substances in the basins themselves with a small pestle. As these substances, when thoroughly dry and warm, are apt to exhibit a strong electrical repulsion of their particles, it is advisable to place the basin on a sheet of glazed paper, by which precaution any portion that may escape from it can be easily replaced. Any particles adhering to the fingers or to the pestle may be swept off with a soft feather. The most scrupulous exactness and accuracy is requisite in these investigations.

Lastly, it must be heated in a chloride of zinc bath to 230° . The loss of weight indicates the quantity of water.

d. An optional quantity (say from 400 to 600 grains) of defibrinated blood, must be boiled over the flame of a spirit-lamp, in order to coagulate the whole of the albumen, and subsequently placed on the water-bath for the purpose of removing all moisture. As soon as the blood has become sufficiently dry to admit of being partially broken up, it must be carefully triturated in a mortar, and then again placed on the water-bath. All the tough coriaceous portions, which are not easily pulverizable, must be carefully removed: by farther drying, they become gelatinous, tough, and ultimately brittle. The powdered blood ought, however, if the previous steps have been properly executed, to assume a flocculent and bright-red appearance, even before it is perfectly dried, and should not exhibit any dark, glittering particles under the process of trituration. If it is black, or of a bad colour, brittle, very tough, and extremely difficult to triturate, it is not fit for the purpose of analysis.

e. This flocculent powder must be reduced to dryness (the trituration being at the same time kept up,) and a small portion (8, 10, or at most 15 grains) weighed in a glass flask for further experiments. If the powder should appear to contain moisture, a small quantity (for instance about 8 grains) may be submitted to a temperature of 230° for a short time, and the whole error from this source may be thus estimated.

I have found that when the powdered blood has been submitted to too strong or too continuous a heat, the spirit-extract is only imperfectly taken up: hence, it may be advisable not to reduce the whole of the powder to a state of absolute dryness, but rather to calculate from a small portion the quantity of retained moisture.

This powder must now be treated with a little anhydrous alcohol. Some ether must then be poured over it, and it must be heated to the boiling point, in order to dissolve the fat as thoroughly as possible.¹

After the deposition of the powder the clear ether must be poured off, and the operation repeated two or three times. The ethereal solutions are then collected, the ether evaporated, and the residual fat submitted for a short time to a heat of 212° , and then weighed.

f. The powdered blood, thus freed from fat, must now (after the ether has been removed by evaporation) be boiled in the same flask

¹ I use small and very thin glass flasks, containing from one and a half to two ounces, (which, like all other apparatus, may be obtained from the establishment of Hoffmann and Eberhardt, of Berlin:) at first I pour on the pulverized blood only about twice its volume of alcohol; I then heat the flask on the sand-bath, keeping it in almost continuous motion, in order that none of it may spirt over, until it boils; I then add a considerable quantity of ether, which precipitates the salts dissolved in the alcohol, so that nothing but fat remains in solution. If too much alcohol has been added, some of the salts remain dissolved, and the apparent weight of the fat is increased. If ether alone be used for the extraction of the fat, the process must be repeated five or six times; the ether should be heated in boiling water just removed from the fire. In using dilute spirit for the purpose of extraction, I heat the flask over the flame of a spirit-lamp. In both cases the flask must be kept in continual motion, in order to regulate the ebullition.

with spirit¹ of .925—.935. This must be effected by gently moving the flask over the flame of a spirit-lamp. The spirituous solution must be allowed to boil freely for some time. All the constituents of the blood are taken up except the albumen: for the salts, extractive matters, hæmaphæin, and hæmato-globulin are all soluble in boiling spirit of .935. The finely divided albumen is gradually deposited from the clear, hot, deep-red solution, which becomes turbid on cooling. On carefully examining a thin section or stratum of the fluid, the presence of albumen or of deposited hæmato-globulin in suspension, may be readily detected. In the first case, in addition to flocculi of a larger or smaller size, there are fine, clearly-defined points to be seen. If the spirituous solution be too thick and consistent to allow of the free deposition of the suspended albumen, the fluid must be cautiously decanted from the sediment into a large glass, and about double the quantity of spirit of .935 added. It must be heated until all the hæmato-globulin is dissolved, and then gradually cooled. When the solution is perfectly cold, we find deposited at the bottom a small quantity of separated albumen, which must be again washed with alcohol into the flask. The residue in the flask must be boiled with spirit of .935 as long as any additional colouring matter is given off: five, six, or even eight boilings are requisite. What now remains is albumen. If the hæmatin has been removed as completely as possible, the albumen, while moist, appears of a grayish-green, and when dried, of a dirty-gray colour; and leaves on incineration a bright yellow residue, containing traces of peroxide of iron. It must be washed out of the flask with a little water, with the aid of a feather; the water must be removed by evaporation upon the water-bath, and the residue submitted to a temperature of 230°, and weighed.

g. The spirituous solutions are collected in a glass, and usually throw down a certain quantity of hæmato-globulin, in the form of flocculi. After the decantation of the fluid, they must be dried upon the water-bath, triturated as finely as possible, rubbed with warm water to a uniform pulp, and washed with spirit of .925. They must be added to the flocculi, of which we shall speak directly. As much alcohol is now added as is sufficient to precipitate the dissolved hæmato-globulin in distinct flocks. If the whole is now allowed to stand for 12—18 hours, all these flocks will be deposited at the bottom of the vessel, and there will remain above them a clear yellow fluid, which must be removed with a syphon, and the last remaining portion with a pipette. The flocks must be washed two or three times with fresh spirit of from .89 to .90, which must be removed by the same means.

If these spirituous solutions are of a yellow or citron colour, we may assume that they contain only salts and extractive matters tinged with hæmaphæin: if they are of a reddish tint, then hæmato-globulin is also present, which must be precipitated by the addition of stronger spirit.

¹ I mix equal parts of alcohol of 85 or 90 $\frac{1}{2}$ with distilled water.

We have now to analyze (i) the flocculi, and (ii) the spirituous solution.

i. a. One or two ounces of alcohol of .83 or .80 (the stronger the better) are poured over the flocks; the mixture is then well stirred, and a sufficient quantity (usually from three to eight drops) of dilute sulphuric acid is added *guttatim*, until a decided change of colour of the flocks is observed. The flocks are now allowed to settle, and the deep red alcoholic solution is decanted. The decolorized flocks are then treated with pure alcohol until they cease to give off any more colouring matter. If, *after this*, the flocks have still a reddish tinge, they must be treated with a little more acidulated alcohol. If the flocks are as free from haematin as possible, they assume a more or less clearly defined gray colour; when dried, they appear as a dirty-gray powder, and on incineration they leave a yellow or orange-coloured ash.

b. The flocks must be washed with alcohol until they cease to exhibit an acid reaction; they must then be washed out of the glass flask (with the aid of a feather and a little water) into a porcelain basin, be dried first upon the water-bath, and subsequently at a temperature of 230° , and then weighed. They are estimated as globulin.

c. The red alcoholic solutions are mixed and saturated with ammonia to such an extent as to emit a decided ammoniacal odour; they are allowed to stand for some hours, in order to allow of the separation of the sulphate of ammonia; they are then filtered, the sulphate is washed with a little alcohol, and the alcohol is subsequently evaporated. The residue consists of haematin with haemaphæin, a trace of fat, and perhaps a little sulphate of ammonia. The latter may be taken up by water, at the risk, however, of losing an almost unappreciable trace of haemaphæin, which is so far soluble in that fluid, as to communicate a yellow tint to it.

d. There may be certain cases in which the perfect separation of the two colouring matters, the haematin and haemaphæin, would be a matter of considerable importance.

In all those cases in which I have found a large proportion of haematin, as in the blood in Bright's disease, and in menstrual blood, a certain portion of haemaphæin is always associated with it. The dark coloured blood of melæna contains a peculiarly large quantity of haemaphæin. The separation of the two colouring principles is best effected by alcohol, which dissolves the haemaphæin, but not the haematin. The alcohol should be warmed, but not allowed to boil. Upon the evaporation of the alcohol the haemaphæin is obtained, and when thoroughly dried, may be weighed.

ii. a. By the evaporation of the alcoholic solutions, we obtain a yellow or brown residue, which has a saltish taste, and smells of extractive matters. It must be thoroughly dried, and then weighed.

b. If we wish to carry the analysis further, a known weight of the residue must be incinerated. The quantity of ash, from 8 to 16 grains

of this residue, will be small, probably from .3 to 1·0 grain. The residue likewise contains sugar, urea, and the colouring matter of the bile; the former may sometimes be detected by the taste, and the presence of the biliphæin may be recognised by the dark colour that it imparts to the serum. In so minute a quantity of material the urea cannot be easily traced.

In my analyses of the blood, I have always followed this course, and I feel convinced that if all necessary precautions are taken, the results will be nearer the truth than those obtained by any previously described method. I do not, however, intend to assert that my method will give *exactly accurate* results; and I shall at once proceed to point out,—1, Those errors against which we may guard by caution; and 2, Those which, with all care, cannot be avoided.

Water. This constituent may be determined with perfect exactness.

Fibrin. If the blood be whipt with due care, the fibrin is obtained as a thick, coriaceous, fibrous mass, surrounding the twigs of the rod. It can be removed without loss, and can be easily and quickly washed.

If it be stirred too rapidly, a portion of the fibrin becomes minutely subdivided, and after washing cannot be collected without some loss; on the contrary, if it be stirred too slowly, or not long enough, the fibrin encloses many blood-corpuscles, and must either lie for some time in water, during which it is liable to a certain degree of change, or else it must be triturated and broken up, which induces the formation of flocks and of a viscid matter, and occasions considerable loss.

With a little experience and practice, the fibrin may be determined with great exactness. It is necessary to submit the dried fibrin to a temperature of 230°.

Fat. The fat contained in the fibrin may be estimated with great accuracy. It is only necessary to boil the pulverized fibrin with ether, or (which is better) with a mixture of ether and anhydrous alcohol, for four, five, or six times. The determination of the quantity of fat in the dried pulverized blood is much less certain and accurate. In an analysis in which I separated the haemaphæin, I treated a large quantity of pulverized blood, six successive times with boiling ether, in a retort; yet I still found a considerable quantity of fat in the haematin. This may be due, partly to the compounds of margaric and oleic acids becoming decomposed by the sulphuric acid in the alcohol during the boiling of the powdered blood which had been treated with ether; and partly, I believe, to a little free fat which had not been taken up by the ether.

The fat appears to be extracted most perfectly when the powdered blood has been first loosened, as it were, with anhydrous alcohol. A

quantity of ether, just sufficient to precipitate the salts dissolved by the alcohol, must then be added. We may safely calculate that the whole of the free fat has been taken up, after six or seven extractions with ether. If, afterwards, the haematin should still be found to contain fat, some of the fatty acids must have been present, and acted upon by the acidified alcohol.

Albumen. Errors may arise in the determination of the albumen. These may be due, in the first place, to want of care in drying and pulverizing the blood. If the powdered blood has been allowed to dry into a cracked, brittle, tough, hard mass, which can only be repulverized with difficulty, and usually with considerable loss, then, only a portion of the haemato-globulin is taken up by the spirit, some of it now appearing of a yellow or gray-green colour, while another part of it occurs in the form of coarse black fragments, resisting the action of alcohol. This albumen has a somewhat red tint, and upon incineration leaves an ash, which is tolerably rich in iron.

Another source of error may lie in the spirit, which may be either too strong or too weak. I have always found a mixture of equal parts of alcohol of 85—90%, and of water, succeed best. I have occasionally found that with all precautions, and after boiling the residue with spirit until no more haemato-globulin was taken up, the albumen has still retained its red tint, and left an ash abounding in iron. I have never been able to ascertain the reason why diluted boiling alcohol should occasionally fail in the perfect extraction of the haemato-globulin.

If, after continuous boiling with dilute alcohol, the albumen still retains a red tint, I heat it with alcohol of .80—.82, in the same flask, and during ebullition I gradually add one, two, or even four drops of dilute sulphuric acid. The alcohol, at first colourless, now assumes a red tint, and the albumen, which is deposited upon standing, is either free from colour, or becomes so after being once more boiled in strong alcohol. It must then be boiled several times in alcohol of 0.925, which takes up the sulphate of globulin, and leaves the albumen.¹ The alcoholic solution of the sulphate of haematin which (unless the alcohol were too dilute) contains no globulin, may be poured into a flask, and united with the fluid, which is subsequently obtained on the separation of the haematin from the globulin. (i, c.)

The sulphate of globulin separates pretty completely in the form of flocks, from its alcoholic solution, on cooling. The supernatant spirit, which frequently has a slightly acid reaction, must be evaporated, till only a little is left; and we must then try whether upon

¹ As sulphate of albumen is insoluble in alcohol, we need not be apprehensive of losing any albumen by this extraction. I have convinced myself, by a special investigation, that spirit of .925 takes up nothing but sulphate of globulin from the pulverized residue of the blood. The fluid, while hot, is perfectly clear, but becomes rather turbid on cooling, in consequence of the separation of fat.

the addition of strong alcohol, any globulin will still be precipitated. The whole of the sulphate of globulin must be added to that which is subsequently obtained from the hæmato-globulin.

If, in accordance with the methods of Berzelius and Denis, the clot is washed for the purpose of obtaining the fibrin, the nuclei and capsules of the blood-corpuscles are entangled in, and increase the apparent quantity of the fibrin; if, however, the fibrin is removed by whipping, according to my method, then the nuclei and capsules remain in the albumen, and increase *its estimated* quantity.

I am not acquainted with any researches tending to show the degree in which the proportions of albumen and fibrin are modified by the adoption of one or other of these methods. Maitland,¹ however, observes that the quantity of fibrin obtained by whipping is less than that obtained by washing the clot. Müller,² on the contrary, thinks that the weight of the nuclei must be extremely small, and that the results obtained by the two methods are very nearly the same. My own opinion is, that the fibrin cannot be determined with accuracy from the washed clot.

Globulin. The globulin can be calculated with considerable accuracy if the albumen has been perfectly freed from the hæmato-globulin. I have never yet succeeded in entirely removing the hæmatin from the globulin. It is known that even nearly colourless globulin leaves, on incineration, an ash which is pretty rich in peroxide of iron. Whether globulin generally contains peroxide of iron or not, I cannot positively state. The globulin usually occurs in analyses of the blood as a sulphate, and as such I have always estimated it. It is of a grayish-white colour, forms a brownish solution in water, and on incineration leaves an ash, more or less abundant in iron.

If after the separation of hæmatin (in the manner already described,) and after being washed in alcohol, the globulin retains a red tint, it must be again treated with a lukewarm mixture of sulphuric acid and alcohol, as before, which dissolves the hæmatin that had remained attached to the globulin. It must then be repeatedly washed with alcohol, until it no longer exhibits any acid reaction.

Hæmatin. From the remarks which have been made respecting the albumen and the globulin, the reader may conclude that the hæmatin cannot always be determined with exactness; I conceive, however, that with all due care, the error in the determination of the hæmatin should be very trifling in 100 parts. It by no means necessarily follows that hæmato-globulin should under all circumstances contain a constant proportion of hæmatin. Moreover, if the fat has not been previously entirely removed, a certain quantity may be associated with the hæmatin. If the hæmaphaein is separated

¹ An Experimental Essay on the Physiology of the Blood, 1838.

² Physiologie des Menschen, vol. 1, p. 119.

from the haematin by means of warm alcohol, the fat dissolves simultaneously with the former of these colouring matters, and remains closely connected with it. If the alcohol used for the separation of the haematin from the globulin is not sufficiently strong; and if, after the saturation of the sulphuric acid with ammonia, a sufficient time is not allowed for the sulphate of ammonia to separate, a portion of this salt will pass through the filter, and become mixed with the haematin upon the evaporation of the alcohol. If this is the case, the salt may be easily recognised in the haematin by its crystalline form; and it must be extracted with water. It is always advisable to use strong alcohol, and to allow the saturated solution to stand for some hours before it is filtered.

Hæmaphæin. The determination of this constituent is somewhat uncertain and difficult, on account of the minute proportion in which it exists. It is occasionally found to constitute only 0·1 $\frac{1}{2}$ of the weight of the dried blood. A portion of this colouring matter is taken up with the extractive matters from which we cannot separate it; another portion may be lost if the alcohol used for the separation of the haematin from the globulin is not of sufficient strength. In this case, on saturating with ammonia, a sulphate of ammonia is precipitated, and its removal is associated with a further loss of hæmaphæin. The hæmaphæin always retains a little fat.

Salts and extractive matters. These substances, with due caution and experience, may be determined with considerable accuracy. They must be separated from the hæmato-globulin by the addition of dilute spirit, and to ensure a tolerably perfect separation, the whole should be allowed to stand from eighteen to twenty-four hours. I have already mentioned the course that must be adopted in case any of the hæmato-globulin should be retained in the alcoholic solution. If the extractive matters and salts are evaporated on the water-bath to a slight residue, and then treated with anhydrous alcohol, the alcohol-extract will be dissolved and may be estimated. I do not know how to separate hæmaphæin from the extractive matters. In order to determine the salts, the extractive matters must be incinerated. By treating the (incinerated) residue with hot alcohol of '85, we take up the chloride of sodium. The residue must be dissolved in a little water, and rendered neutral by the addition of acetic acid. The acetates of potash and soda may now be taken up by alcohol. These salts correspond with the lactates.¹ There

¹ [The existence of lactic acid and the lactates in the animal fluids is denied *in toto* by the Giessen school.

Enderlin's conclusions regarding the recently incinerated ash of blood may be summed up in the following terms:

1. The ash does not effervesce on the addition of an acid.
2. Hot water poured on the ash becomes alkaline; it holds in solution alkaline phosphates and sulphates, chloride of sodium, and sometimes chloride of potassium, but no other salts.
- a. On the addition of a neutral solution of nitrate of silver to this fluid, there is a yellow

still remain the phosphates and sulphates of lime, magnesia, potash, and soda. If they are dissolved in a little dilute nitric acid, the addition of ammonia induces the precipitation of the earthy phosphates, while the other salts remain in solution.

There are some substances occurring only in very minute quantities, or in certain diseased states, which cannot be always easily detected.

1. *Urea.* This substance has never yet been observed in any great quantity in the blood.

I have detected a minute quantity of urea in the blood of a healthy calf. I allowed the blood (about fifteen or sixteen pounds) to run into a vessel filled with alcohol, and assiduously stirred the mixture. The alcohol was removed by pressure, evaporated, and the residue extracted with anhydrous alcohol. After filtration, and a second evaporation, the residue was again dissolved in a little anhydrous alcohol, and the bases of the lactates and fatty acids precipitated with sulphuric acid. The filtered liquid was digested with carbonate of baryta, evaporated, dissolved in water, the fats and fatty acids removed by filtration, the aqueous solution concentrated, and nitric acid added. The greater part of the fluid was removed by being placed *in vacuo* over strong sulphuric acid; alcohol was poured over the residue, and the solution submitted to spontaneous evaporation. The microscope then revealed the presence of nitrate of urea, which was recognised by its peculiar crystalline form.

[Marchand got only slight microscopic indications of urea from twenty pounds of the serum of the blood of a healthy cow; and as the urine of that animal contains a larger amount of urea (4% according to Sprengel) than that of man, the blood must likewise contain a larger proportion of this ingredient. He calculates (assuming that there are twenty pounds of blood in a man's body, and that one

precipitate, which is partly soluble in nitric acid; a portion, however, consisting of chloride of silver, remaining undissolved. The addition of nitric acid causes no effervescence. On neutralizing the acid filtrate with ammonia, a yellow precipitate of tribasic phosphate of silver ($3\text{AgO}_2\text{PO}_4$) is thrown down.

b. On treating the aqueous solution of the ash with a solution of chloride of calcium, there is a copious gelatinous precipitate of phosphate of lime ($3\text{CaO}_2\text{PO}_4$) which dissolves in nitric acid without effervescence. On treating this acid solution with nitrate of silver, and neutralizing with ammonia, the tribasic phosphate of silver is precipitated as before. The addition of the chloride of calcium neutralizes the previously alkaline fluid.

From 1, we see that the alkaline reaction is not due to the presence of alkaline carbonates; and 2 shows it is not dependent on the presence of free potash or soda, for otherwise the fluid would not be neutralized by the chloride of calcium. Hence the albumen in the blood cannot exist as a soda-compound (aluminatite of soda); neither can there be alkaline lactates, acetates, nor fatty-acid salts in that fluid; and on the above grounds, Enderlin conceives that we are justified in assuming that the alkaline reaction of the ash is dependent on the presence of tribasic phosphate of soda ($3\text{NaO}_2\text{PO}_4$); and as this is the only salt that remains tribasic at a red heat, he concludes that the alkalinity of the blood, as well as of the ash, is dependent on it. Enderlin is the only chemist who excludes carbonates from the ash of the blood and other animal fluids. The manner in which he accounts for the occurrence of these salts in the analyses of other chemists is very plausible. On exposing $3\text{NaO}_2\text{PO}_4$ to the atmosphere, it becomes converted into $2\text{NaO}_2\text{HO}_2\text{PO}_4$ and NaO_2CO_3 . (Liebig and Wöhler's Annalen der Chemie und Pharmacie; March, 1844.)]

ounce and a half of urea is eliminated in twenty-four hours) that the blood contains only the 15,360th part of its weight of urea, a quantity that could hardly be determined analytically, if it were increased thirty-fold.]

After the extirpation of the kidneys, and in Bright's disease, it has been found in so large a proportion that its detection is accomplished with comparative ease. My method, in looking for urea, is to treat a certain quantity of the blood with alcohol for the purpose of throwing down the protein-compounds; then to filter; and, subsequently, to wash the residue upon the filter with alcohol. The alcoholic solution (including the washings of the filter) must be evaporated to a small residue, and treated with anhydrous alcohol. The solution is decanted from the spirit-extract, which remains undissolved, is evaporated, and again treated with anhydrous alcohol. This process must, if necessary, be repeated until the residue is freely soluble in this menstruum.

The alcohol must then be evaporated, and the residue dissolved in water, which usually becomes slightly turbid in consequence of the separation of traces of fat. This fat is not easily separated by filtration; if, however, this process is determined upon, a considerable quantity of water is added; it is heated, and allowed to stand for some time. The watery solution will then pass through the filter tolerably clear, but slowly. It must be evaporated to a small residue, thoroughly cooled, and nitric acid then added. If the quantity of urea is not too minute, there are formed almost instantaneously an immense number of glittering crystalline scales. If the quantity of urea is *very minute*, the crystallized nitrate of urea may not be perceptible for several hours, and even then probably not without the aid of the microscope. In order to avoid any errors that might arise through the crystalline form of other salts, I first made myself thoroughly acquainted with the appearance presented under the microscope by alcohol-extract of urine (containing urea) when treated with nitric acid; then with the appearance presented by alcohol-extract of blood to which a little urine had been added, on the addition of nitric acid; then with that of alcohol-extract of blood devoid of urea; and, lastly, with blood which contains urea in the natural proportions. In this manner I found that the salt which most commonly occurs in the alcohol-extract of blood, the lactate of soda, may be readily distinguished under the microscope from the nitrate of urea, and that very minute quantities of urea may be detected with certainty.

Small quantities of urea may be recognised, by the peculiar and characteristic form of the nitrate, in fluids containing those extractive matters and salts of urine or of blood that are soluble in anhydrous alcohol. The forms which are principally and most frequently ob-

¹ [That there is a peculiar difficulty in the precise determination of this constituent is shown by an experiment in which Marchand mixed one grain of urea with 200 of serum. He could only recover $\frac{3}{4}$ of a grain.]

served are depicted in fig. 3: *a* represents the characteristic crystalline form of nitrate of urea; *b, c, d, e*, groups that are formed in a somewhat dilute solution of urea; *f*, groups that are formed in a very dilute solution, chiefly at the edge of the fluid. Fig. 4 exhibits the crystalline form which is produced by the addition of nitric acid to the alcohol-extract of blood, containing no urea. These crystals are not perceptible until the fluid is evaporated nearly to dryness. Fig. 5 shows the form of the nitrate of urea in blood containing a considerable quantity of urea. I have several times observed these appearances in Bright's disease. With a little practice the commencement of the crystallization of the nitrate may be perceived; it begins by exhibiting an appearance of numerous fine parallel lines or streaks.

Oxalic acid may likewise be used in microscopic researches regarding the presence of urea in the blood. I have always, however, preferred the use of nitric acid, because, in the first place, it is not itself capable of crystallization as oxalic acid is; and, secondly, because the nitrates of potash and soda are much more soluble than the corresponding oxalates. Fig. 6 shows the crystalline form of the oxalate of urea when alcohol-extract of urine, not very rich in urea, is treated with oxalic acid. In *a*, we see the characteristic crystalline form of the oxalate of urea; *b*, represents various groups of it. If the alcohol-extract of blood containing no urea be similarly treated, the crystals of fig. 7 are produced. Lastly, fig. 8 shows the crystals of oxalic acid itself, which are very similar to those of pure crystallized urea.

On treating the extractive matter of blood containing no urea with nitric acid, I have occasionally perceived crystals which, at first sight, appeared extremely similar to those of nitrate of urea, but which were in reality composed of nitrate of soda. These crystals are exhibited in fig. 9. They possess a very remarkable degree of thickness,¹ which I have endeavoured to represent in the plate. They may be distinguished from the similar form of nitrate of urea, by the circumstance that the former are not at all soluble in anhydrous alcohol, while the latter are readily dissolved in it. If nitrate of urea be present, it will recrystallize from its alcoholic solution in groups similar to those in fig. 10.

2. Sugar. This substance, which I once discovered in the blood of a calf, is very seldom to be found in healthy blood, although in certain pathological states, especially in diabetes mellitus, it has frequently been detected. If the quantity be very small, its presence is not always easily recognised. It is found mixed with the extractive matters, if the blood is analyzed according to my directions, and if it exists in any quantity, may be recognised by the taste. If only a very little sugar be present, it is advisable to precipitate the protein-compounds from a large quantity of blood, with spirit. The

¹ This is easily seen by slightly varying the focus.

fluid must then be filtered and evaporated to a small residue, which must be treated with anhydrous alcohol. The sugar, if present, must be taken up by the alcohol. If, after due evaporation, the residue have a sweetish taste, a portion of the sugar may be obtained tolerably pure, since its quantity cannot be very inconsiderable. With this view we dissolve it in a little water, add alcohol of '833, and allow it to stand for some time; under favourable circumstances, a portion of the sugar will crystallize. In consequence of its intimate mixture with a large quantity of extractive matter, an exact quantitative analysis of the sugar is extremely difficult. The best method is that of fermentation, and estimating the quantity of carbonic acid that is formed. If the quantity of sugar be very minute, it cannot be recognised by the tongue, in consequence of the sweetness being disguised by the taste of the salts and extractive matter; it may, however, in this case, be detected by sulphuric acid, although this test is fallacious in the hands of unpractised analysts. The method to be pursued in this case is the same as that previously indicated; the spirituous solution must be evaporated, treated with anhydrous alcohol, and the fluid decanted. The precipitate which contains extractive matter, chloride of sodium, lactate of soda, and sugar, must be dissolved in water; and if (as is frequently the case) any haemato-globulin remains undissolved, the fluid must be filtered. The filtered fluid must be evaporated to dryness in a porcelain basin, on the water-bath, and one or two drops of dilute sulphuric acid (one part of acid to six of water) must be dropped upon the dried residue. On again submitting it to the heat of the water-bath, it is observed that those points which have been moistened by the acid at first assume a blue or violet tint, become gradually darker, and ultimately coal-black. When the quantity of sugar is very small, the colour is only sufficiently marked at the margin of the drop, or at points where the layer of extractive matter happens to be particularly thick. Unfortunately for the success of this test, a dark spot, varying from a deep brown to a dark dirty-violet tinge, but never positively black, is produced in the same manner in the spirit-extract of blood, which contains no sugar; so that, without a well-practised eye, it is difficult to decide upon the absence or presence of sugar by this test. After the addition of one grain of diabetic sugar in solution, to 500 grains of blood, (which contained no sugar,) no decided sweetness could be observed in the spirit-extract. The sulphuric acid test indicated the presence of sugar by the formation of a coal-black spot; on the addition of the acid to a portion of the extract of the same blood in which there was no sugar, a dirty violet spot was produced. In examining the blood of diabetic patients I once found so large a proportion of sugar that it was readily detected by the taste; on another occasion, however, it was only rendered manifest on the addition of sulphuric acid. But of all the tests for sugar in the blood, Trommer's is certainly the best. The protein-compounds are first precipitated with anhydrous alcohol, and dry carbonate of potash is then added to the filtered spirituous so-

lution, which must be well shaken. On the addition of a little solution of sulphate of copper, and the application of heat, we observe, if sugar be present, a yellow or yellowish brown tint developed, produced by the reduction of the copper to a state of suboxide.

3. Bile. In healthy blood we find neither bilin nor biliphæin. In icterus we meet with biliphæin in the serum, which is more or less deeply coloured in proportion to the quantity of this pigment contained in it. It may be of a deep orange, or almost red colour, so as to lead to the suspicion of the presence of hæmatin in a state of solution. I found the serum nearly blood-red in a case of icterus; but on shaking it against the sides of the vessel, the thin adhering layer appeared of a beautiful saffron colour. A similar colour was induced by the addition of water to the serum.

If only so small a quantity of biliphæin be present as to colour the serum slightly, it may be recognised by the addition of nitric acid, which produces a variety of tints, more or less green in their character. The albumen is at the same time precipitated in white flocks, upon which a slight tinge of green may be distinctly perceived.¹ In the deep red serum already alluded to, the addition of nitric acid produced an intensely clear grass-green colour, which, at some points, passed into a blue, and, in the course of twenty-four hours, into a yellow tint. The quantity of biliphæin varies directly with the intensity of the colour of the serum, and with the time required for the disappearance of the green tint, produced by the addition of nitric acid. Neither in the blood already alluded to, nor in another specimen which contained less biliphæin, could I discover a trace of bilin. The alcohol-extract of the blood had a saltish, but not a bitter taste. I am not aware that bilin or bilifellinic acid² has ever been observed in the blood, and I hardly believe that they will be found, owing either to their not being taken up by the blood at all, or else to their speedy elimination by the urine. A large quantity of bilin would have a very dangerous effect upon the blood, since (as we have already shown) it dissolves the blood-corpuscles. I treated 500 grains of blood with half a grain of inspissated ox-bile, and then precipitated the protein-compounds with spirit, evaporated the fluid, and treated the residue with anhydrous alcohol. It is clear that the bile must be contained in this residue. After the evaporation of the alcohol, there remained a rather dark-coloured extract, having a bitter bile-like taste, and which, when dissolved in water, and nitric acid was added, manifested a slight green tinge. If, therefore, the bilin should constitute one-thousandth part of the blood, it would be easily detectible.

¹ [In consequence of the facility with which coagulated albumen assumes a green tint under these conditions, we are often enabled to detect biliphæin (that would be otherwise unappreciable) in non-albuminous fluids, by the addition of a little albumen.]

² [Enderlin states that he has detected minute quantities of choleste of soda (pure bile, according to Demarçay's theory) on three occasions, in the blood of calves and oxen. (Annalen der Chemie und Pharmacie, April, 1844.)]

If the analysis of the fats and of the extractive matters is to be thoroughly carried out, (as in many cases it certainly ought to be,) much larger quantities of blood must be taken than I have made use of.

The various fats, however, as well as the different extractive matters, are at present too little known to enable us to attempt exact, or even approximating quantitative analyses.

4. Fats. Boudet¹ has analyzed the fats which are taken up by alcohol from dried blood, after all substances that could be extracted by water have been removed. The alcoholic solution deposits serolin on cooling, which must be separated, and the alcohol evaporated. There remains as a residue a mixture of several fats, which were separated by Boudet in the following manner. Cold alcohol of .833 leaves undissolved a crystalline fat which contains phosphorus, and is apparently similar to the brain-fat, denominated *cerebrot* by Couerbe. Cholesterin is deposited by the spontaneous evaporation of the cold alcoholic solution; and on further evaporation, (after the removal of the cholesterin,) there is left a mixture of oleic and margaric acids, as well as some oleate and margarate of potash. In addition to these fats, there are certain coloured phosphorized and nitrogenous fats, similar probably to those which have been described by Couerbe, as *cephalot* and *eleencephol*. Lecanu found, in the fat of the serum, only cholesterin, serolin, margaric and oleic acids; he could detect no phosphorized fat. Berzelius² describes the fat of the fibrin, which may be taken up either by alcohol or ether, as solid and crystalline; when melted, of a yellow or light brown colour, readily soluble in cold alcohol, to which it imparts an acid reaction, indicating the presence of one or more of the fatty acids. Upon burning it, no acid ash is left.

Denis,³ on the other hand, obtains from fibrin, as well as from albumen and haemato-globulin, a red phosphorized fat, which has an alkaline reaction. By digestion in caustic potash, a part is dissolved, while an insoluble portion remains, in the form of a white, saponified powder, readily soluble in ether, from which it may be again obtained, by spontaneous evaporation, in the form of delicate crystals, which burn like fat.

The portion of saponified fat which is dissolved in the potash must be precipitated by hydrochloric acid, and cannot be melted in the acid fluid, even on raising the temperature to a boiling heat. After having been removed by filtration, it is found to be soluble in alcohol and ether, and we may obtain it, after evaporating the fluid in which it is dissolved, as a fat, which becomes fluid at a temperature of 97°—104°, but is solid at an ordinary temperature. It has an acid reaction, and swells up, but is only very partially soluble in boiling water, from which, on evaporation we obtain it (the dissolved portion) as a sort of film or coating.

¹ Annales de Chem. et de Phys., vol. 52, p. 337.
² Recherches Experimentales, &c. p. 101.

³ Thierchemie, p. 88.

According to Berzelius, it is similar to the acid salts of stearic and oleic acids described by Chevreul; it differs from them, however, by its greater solubility in ether and cold alcohol.

5. Extractive Matters. These substances have been less carefully analyzed than the fats, and the proportions in which they occur, are so small, that even in the analysis of a large quantity of blood, their exact determination is no easy matter. All that is known upon the subject is already given in the Introduction.

[A simple method of determining some of the most important constituents of the blood has been recently given by Figuier. It is based on the fact, made known many years ago by Berzelius, that after the addition of a solution of a neutral salt to defibrinated blood, the globules do not (as before) pass through filtering paper. On the addition of two parts of a solution of sulphate of soda of spec. grav. 1.130 to one of blood, Figuier found that the whole of the corpuscles remained on the surface of the filter. The following are the steps of his analysis. The fibrin is removed by whipping, dried, and weighed; the weight of the corpuscles is ascertained by the method indicated; and that of the albumen by coagulating, by means of heat, the filtered solution. The proportion of water is determined by evaporating a small known weight of the blood.]

Analysis of coagulated blood.

It sometimes happens that we receive blood for analysis that has already coagulated. The process to be adopted in such cases, although not in reality more difficult, involves a greater amount of chemical manipulation than when the fibrin is separated by whipping; and it appears to give less exact results.

The directions that I shall now give for the analysis of coagulated blood were published in a paper of mine some time ago;¹ I have, however, only once adopted this method, as I always prefer analyzing the blood directly it is taken from the body.

The whole of the blood must first be weighed as accurately as possible, the clot must then be removed, and if sufficiently consistent, dried between folds of blotting paper, and then weighed. A portion of the clot (from 40 to 80 grains) is cut off, and its weight accurately taken; it is then thoroughly dried and the loss of weight, which indicates the quantity of water, ascertained: the dried residue must be reduced to a spongy, bright-red, fine powder, and treated with ether in order to remove the fat: it must subsequently be treated with boiling alcohol of .925 until the spirit ceases to take up any additional colouring matter, and the powder which remains has a dirty-gray or gray-green colour. This must be thoroughly dried, and estimated as *fibrin* and *albumen*. The reddened alcoholic solution, A, is set aside for farther operation.

¹ Brande's Archiv. vol. 2d.

Another portion of the clot must be weighed and placed in a porcelain mortar, which should be provided with a pestle of such a size as exactly to fill it. Moreover, the edge of the mortar should be about one-third of an inch above the head of the pestle. By this arrangement none of the clot can be lost. It must be reduced to a fine pulp, which must be treated with water until the flocculi of fibrin become perfectly white: these must be carefully collected and dried.

By the subtraction of the weight of the fibrin from that of the former residue, we obtain the weight of the albumen.

Before analyzing the serum, it must be well shaken in order to render its constitution uniform; a portion must then be weighed, coagulated at a boiling heat, thoroughly dried, again weighed, and the proportion of water thus estimated. The dried residue must be finely pulverized, the fat removed by ether, and it must be then boiled with alcohol of .925 until every thing which is soluble in that fluid has been taken up.

The residue consists of albumen, which must be dried and weighed. The alcoholic solution must be added to the solution A, and these mixed fluids analyzed for the globulin, hæmatin, hæmapbæin, extractive matters and salts, in exactly the same manner as described in page 146.

ON THE HEALTHY BLOOD IN RELATION TO PHYSIOLOGY.

(*From my own analyses.*)

It is almost unnecessary to observe that the blood of one and the same individual may vary in its constitution at different times, and under different circumstances. We shall proceed to investigate the causes upon which these variations depend.

Amongst the most obvious causes we may place the proper supply, or the absence of sufficient nutrition.

The blood will clearly abound in water, in proportion to the quantity of fluid with which it is supplied; it will abound in albuminous constituents, in fats, and salts, in proportion to the richness of the nutriment that has been taken, and of the chyle that has been evolved from that nutriment. In order to counteract the evils that might arise from an excess of water in the blood, (which, if allowed to remain unchecked, would induce too rapid a solution of the blood-corpuscles,) the kidneys, skin, and lungs exert an active agency; while, on the contrary, if there be a deficiency in the proportion of the water, caused either by too great exhalation, dependent upon excessive fatigue, or by a direct accumulation of the salts (which might impede the solution of the corpuscles) it is immediately indicated by an urgent desire for drink.

When substances, injurious to life, are taken into the stomach, only small quantities enter the blood, the great proportion being usually carried off by the intestinal canal, and by the organs of ex-

cretion and secretion. If the organism be unequal to the task of rejecting the injurious agent, the equilibrium of the system is destroyed, and death ensues.

Another cause of the varying nature of the blood, interesting equally to the physiologist and the physician, may be referred to the modifications that it undergoes in the nutrition of the organism, and to the changes undergone by the corpuscles, in connexion with the processes of secretion and excretion.

On the distinctive characters of arterial and venous blood.

The distinctive colours of arterial and venous blood are too well known to require any observation.¹

Arterial blood, on being whipt, allows the fibrin to separate in short conglobate masses, more tenacious and compact than the fibrin of venous blood.

The odour of arterial blood is considered to be stronger than that of venous. The temperature is also usually stated to be different, Jurine being the only experimentalist who assigns an equal temperature (i. e. $102^{\circ}.2$) to both forms of blood. According to Scudamore, the temperature of arterial blood in man is $1^{\circ}.8$, according to Kramer, $2^{\circ}.7$, higher than venous blood. Dr. Davy found the difference in animals amount to $3^{\circ}.6$. The observations of Coleman, Cooper, and Martini are directly opposed to the above statement. (Lecanu, *Etudes Chimiques sur le Sang.*)

¹ [From Scherer's experiments it appears that, when fresh red ox-blood is deprived of its fibrin and diluted with twice or thrice its volume of water, it assumes a dark venous tint, which is not affected by the passage of a current of oxygen through it. On the addition, however, of a little milk, oil, finely-powdered chalk or gypsum, the original bright red colour is evolved. These experiments are sufficient to prove that the bright red colour is dependent on other causes than oxidation, and that the dark venous tint does not arise from carbonic acid or carbon; in fact, Scherer conceives that they prove that the former is dependent on the presence of white particles of chyle suspended in the fluid, an opinion confirmed by the microscope. It was observed by Hewson that, when the colour of the blood is bright red, the corpuscles are always biconcave; they reflect a large amount of light, and in this respect act as the chalk, milk, &c. in Scherer's experiments. When, on the other hand, the blood is of a dark colour, the corpuscles are biconvex, and the capsule is so thin as to admit of the easy passage of the whole light through it; moreover, on account of its attenuation, it bursts, and allows of the escape of its contents, as may be observed on the addition of water to red blood. If the blood remain in contact with water till a dark tint becomes apparent, and a saturated solution of a neutral salt be then added, the corpuscles again become biconcave, in consequence of their being partially emptied by the endosmosis called into play by the different fluids within and without the capsule; and the capsules themselves, and the original bright red colour reappear. A current of carbonic acid gas passed through fresh red blood renders the corpuscles biconvex, and makes the blood assume a dark venous hue.]

Mulder explains the difference between the colour of arterial and venous blood in the following manner: Two oxides of protein are formed in the act of respiration; they have a strong plastic tendency, and solidify round each corpuscle, making the capsule thicker and better qualified to reflect light. Each corpuscle of the arterialized blood is then in reality invested with a complete envelope of buffy coat, which gradually contracts, and speedily forms the cupped or biconcave surfaces, which, as we have already shown, are favourable to the reflection of light. On reaching the capillaries, the coating of the oxides of protein is removed, and the corpuscles, losing their opaque investment and their cupped form, can no longer reflect light, and the blood assumes a venous tint. (Mulder's *Versuch einer allgemeinen physiologischen Chemie*, pp. 344-59; or Dr. G. Bird's account of Mulder's Researches, in the *Medical Gazette*, December, 1844.)

The relative capacity for heat of arterial and venous blood is, according to Davy, as 839 to 852.

There is considerable difference of opinion among physiologists with respect to the specific gravity of arterial and venous blood: Hammerschmidt, Davy, Scudamore, and Letellier assert that the density of arterial is lower than that of venous blood; the former being represented by 1039·8—1042·9, the latter by 1053—1056.

Boissier and Hamburger, on the contrary, found arterial denser than venous blood.

The observations of Bellingeri¹ respecting the electric relations of arterial and venous blood are very singular.

In birds, horses, and occasionally in sheep and calves, both forms of blood are in the same electric state. In other animals the arterial blood is positively electric in relation to the venous. The reverse has never been observed.

Observations have also been made regarding the comparative tendency to putrefaction of arterial and venous blood. Krimer and Kanig assert that arterial blood is the most prone to decay; Thackrah, on the contrary, makes a similar statement respecting venous blood.

In order to obtain any correct information with regard to the differences that undoubtedly exist in the composition of arterial and venous blood, it is necessary to have recourse to accurate chemical analyses. I have devoted much attention to this point, and fully concur with Schultz, Dumas and Prevost, and others, in the belief that the two forms of blood present marked differences of constitution.

I made use of the blood of horses in these experiments, and was kindly assisted by Professor Gurlt. The carotids, from which we obtained the arterial blood, were exposed, and opened in such a manner as to ensure the absence of any venous blood: the venous blood was obtained from the jugulars.

The analyses were made according to my ordinary method (vide supra,) and gave the following results.²

1000 parts of blood contained:

		Analysis 1. Arterial blood.	Analysis 2. Venous blood.
Water	- - - - -	760·084	757·351
Solid residue	- - - - -	239·052	242·649
Fibrin	- - - - -	11·200	11·350
Fat	- - - - -	1·856	2·290
Albumen	- - - - -	78·880	85·675
Globulin	- - - ; -	136·148	128·698
Hæmatin	- - - - -	4·572	5·176
Extractive matter and salts	- -	6·960	9·160
100 parts of the blood-corpuscles contained 3·4 of hæmatin.		100 parts of the blood-corpuscles contained 3·9 of hæmatin.	

¹ Quoted by Lecanu. *Etudes Chimiques sur le Sang humain*, p. 75.

² It must be observed that no sound horses were used for these experiments, but only those intended for anatomical purposes. Some were too old and weak to be of any use; others were suffering from incurable disorders. Although it may be fairly questioned whether the composition of the blood in these animals is normal, the correctness of the comparative results must be unaffected as long as the lungs and other secreting and excreting organs remain

The horse, which was suffering from malleus humidus, had taken its ordinary food up to the time of its death.

		Analysis 3. Arterial blood.	Analysis 4. Venous blood.
Water	- - - - -	789-390	786-506
Solid residue	- - - - -	210-610	213-494
Fibrin	- - - - -	6-050	5-080
Fat	- - - - -	1-320	1-456
Albumen	- - - - -	113-100	113-350
Globulin	- - - - -	76-400	78-040
Hæmatin	- - - - -	3-640	3-952
Extractive matter and salts	- - - - -	10-000	10-816
100 parts of blood-corpuscles contained 4-5 of hæmatin.		100 parts of blood-corpuscles contained 4-8 of hæmatin.	

This was a meagre horse, killed in consequence of debility and old age.

From these analyses we are led to the conclusion that *arterial blood contains less solid residue generally than venous blood: it contains less fat, less albumen, less hæmatin, less extractive matters and salts than venous blood. The blood-corpuscles of arterial blood contain less colouring matter than those of venous blood.*

There does not appear to be any fixed relation between the fibrin and globulin (or, which is nearly the same thing, the mass of the blood-corpuscles,) in the contrasted analyses; for in Nos. 1 and 2 the fibrin in the venous exceeds that in the arterial blood, while in Nos. 3 and 4 we observe exactly the reverse. The same fluctuation is observable with respect to the globules, or the mass of the blood-corpuscles.

In an analysis of the blood of a healthy ox, made with the same object, I found the quantity of fibrin to be larger in the arterial than in the venous blood. In the former case it amounted to 4-90, and in the latter to only 4-82 in 1000 parts.

I shall now give the results obtained by other chemists upon this subject: I must, however, observe that their methods of analysis differ considerably from mine, and that I consider some of their results questionable.

Denis analyzed the blood of the hound. He found in 1000 parts:

		Arterial blood.	Venous blood.
Water	- - - - -	830-0	830-0
Fibrin	- - - - -	2-5	2-4
Albumen	- - - - -	57-0	58-6
Hæmato-globulin	- - - - -	99-0	97-0
Extractive matter and salts	- - - - -	11-0	12-0

In this instance both kinds of blood contain an equal proportion of solid residue: the former contains, as I have already observed in two out of three analyses, a larger quantity of fibrin. Denis found, as I have also done, that the quantity of albumen, and of extractive matters and salts, is less in arterial than in venous blood.

healthy, provided there is no reason for supposing that the general metamorphosis of the blood is morbidly affected.

Hering¹ has analyzed both kinds of blood in the bullock, the sheep, and the horse. In the blood of the bullock he found in 1000 parts:

	Arterial blood.	Venous blood.
Water	798·9	794·9
Fibrin	7·6	6·6
Albumen	26·1	25·8
Hæmato-globulin	164·7	170·4
Extractive matter and salts	2·7	2·3

In the blood of the sheep he found in 1000 parts:

	Arterial blood.	Venous blood.
Water	850·2	841·2
Fibrin	6·1	5·3
Albumen	33·6	26·4
Hæmato-globulin	106·1	124·4
Extractive matter and salts	4·0	2·7

In the blood of the horse he found in 1000 parts:

	Arterial blood.	Venous blood.
Water	839·5	831·6
Fibrin	4·6	6·9
Albumen	22·0	26·7
Hæmato-globulin	130·0	131·1
Extractive matter and salts	3·0	3·7

These analyses correspond very well with each other, and corroborate our remark, that arterial leaves a smaller amount of solid residue than venous blood. In the bullock and sheep the fibrin in arterial exceeds that in venous blood; in the horse the reverse is observed. The same observation holds good with regard to the albumen, and in this respect (at least in the case of bullocks' and sheep's blood,) Hering's results differ from those of Denis and myself.

Hering invariably found the quantity of blood-corpuscles to be greater in venous than in arterial blood; the proportion of extractive matters and salts are, however, extremely fluctuating.

Lecanu² has likewise analyzed the blood of the horse, and found in 1000 parts:

	Blood of aorta.	Blood of vena cava descendens.
Water	783·83	795·679
Blood-corpuscles	122·68	106·759
Albumen with its salts, ex- } tractive matter and salts } <td>93·49</td> <td>97·562</td>	93·49	97·562
	Blood of carotid.	Blood of jugular vein.
Water	785·5	804·55
Blood-corpuscles	125·6	111·03
Albumen with its salts, ex- } tractive matter and salts } <td>88·9</td> <td>84·45</td>	88·9	84·45

These analyses differ from my own, and from those of Denis and Hering, in assigning to arterial a larger solid residue than to venous blood.

The quantity of blood-corpuscles is also greater in arterial than in

¹ Physiologie mit steter Berücksichtigung der Pathologie für Thierärzte. Stuttgart, 1832, p. 118.

² Etudes Chirurgiques sur le Sang humain. Paris, 1837, p. 83.

venous blood, and Lecanu found the same to be the case with regard to the quantity of fibrin. The quantity of albumen fluctuated.

Schultz¹ observed that the venous blood of hungry and starving horses contained a larger amount of solid residue than the arterial, in the proportion of 186 to 155 in 1000 parts of blood: in a well-fed horse the reverse was the case, the solid residue of the arterial being to that of the venous blood, in the proportion of 229 to 195. The quantities of fibrin were very fluctuating: on one occasion the fibrin of the arterial was to the fibrin of the venous blood in the proportion of 5·3 to 8·1; on another occasion as 9·2 to 9·0. The hæmato-globulin (which he considers identical with the colouring matter of the blood,) was found to vary directly with the darkness of the blood's colour, and consequently to be more abundant in venous than in arterial blood.² The reverse was the case with respect to the albumen.

Autenrieth, and Prevost and Dumas,³ found a greater proportion of solid constituents in arterial than in venous blood: Lassaigne, like myself, found just the reverse: whilst Letellier asserts that there is no fixed rule on the subject.

Müller⁴ and Berthold⁵ observe that in the goat there is a larger proportion of fibrin in arterial than in venous blood: the latter chemist extends the statement to the blood of the cat and the sheep. The observations of Sigwart⁶ and Lassaigne⁷ are opposed to these statements.

Prevost and Dumas obtained from arterial a larger proportion of blood corpuscles than from venous blood, and in this respect they confirm the observations of Lecanu and Denis. My own analyses, and those of Letellier, tend, however, to show that the proportion is a fluctuating one.

Hence we are led to the conclusion that there are certain differences in the composition of arterial and venous blood, which, however, are not constant, but vary according to circumstances.

The most important of these circumstances are the general health of the individual, and the mode of nourishment, whether dependent upon or independent of the health.

Let us now consider what must be the qualities of arterial and venous blood when all the functions of the organism are properly discharged, when the nutrition exactly corresponds with our actual

¹ System der Cirkulation, p. 138.

² In order to avoid the error that might arise in the determination of the hæmato-globulin from the retention of serum in the clot, Schultz proceeded in the following manner: He dried the clot, and subtracted from its residue the amount of solid matter left by a quantity of serum corresponding to the expelled moisture. The difference he regarded as hæmato-globulin. We must not, however, forget that the hæmato-globulin does not exist in a dry state in the blood; and, further, that there are no grounds for assuming that the fluid in which it is held in solution is serum.

³ Annales de Chimie et de Phys., vol. 13.

⁴ Physiologie der Menschen, vol. 1, p. 119.

⁵ Burdach's Physiologie, p. 281.

⁶ Reil's Archiv. vol. 12, p. 5.

⁷ Journal de Chimie Med., vol. 1, p. 34.

wants, and when the blood undergoes the various changes that we have described in a former page.

Under these circumstances we arrive *a priori* at the conclusion that the final result of the changes in the blood during the act of circulation must necessarily be this: there must be a substitution of fresh and proper nutriment to supply the place of those constituents of the blood which are being perpetually consumed; for it is obvious that if in each circulation the consumption of albumen or haemoglobin exceeded the supply by the merest trace, after a certain period the blood would acquire an abnormal constitution. We know that albumen, fibrin, and salts are consumed in the nutrition of the peripheral system; if, therefore, the blood receives no fresh supply of these substances, before it arrives in the larger venous trunks, it is clear that the venous blood must be poorer in these substances than the arterial.

The blood also conveys away from the peripheral system various products formed by the consumption of the tissues; for instance, certain salts, extractive matters, &c., some of which are eliminated by the kidneys, in a state of great dilution, while others are removed by the skin. If the quantity removed exceed the supply, the venous blood will be poorer in extractive matters and salts than the arterial; it will be richer in these substances if the reverse be the case.

The venous blood will contain more or less water than the arterial, according as the elimination of water by the kidneys, liver, skin, and lungs, exceeds or is less than the quantity supplied by the fluid of nutrition.

The blood-corpuscles, and the germs from which they are developed, are likewise supplied to the blood by the nutrient fluids. They are farther developed, and ultimately dissolved during the course of the circulation, and their development and solution is especially facilitated at those points where the action of oxygen on the blood is the most powerful.

It is obvious that the blood, immediately after having received the chyle, must contain more blood-corpuscles than before; it depends, however, upon several circumstances whether venous generally contains more or less corpuscles than arterial blood.

The plasma receives a supply of fibrin from the solution of the blood-corpuscles; if the supply exceeds the consumption of this constituent in the peripheral system, the venous blood may become richer in fibrin than the arterial.

If any albumen should be produced by the solution of the blood-corpuscles, it may be regarded as a substitute for the portion of that constituent which has been taken up from the blood for the nourishment of the tissues.

From these observations we are led to conclude that there is no necessary variation in the composition of venous and arterial blood. The organism, when free from disturbing influences, possesses in itself

various means of regulating the due admixture of its different juices, and more especially of that most important vital fluid, the blood.

Amongst these means we may place the influence of the nervous system, its power of increasing or lessening the action of the secreting and excreting organs, and of inducing in them either co-operating or vicarious action.

The differences in the constitution of arterial and venous blood cannot, however, by any possibility, be very great. In my analyses they usually fluctuate between fractions of a hundredth part; and they appear to be less between analyses 3 and 4, than between analyses 1 and 2, since the former (anal. 3 and 4) were made on the blood of an old, decrepit, half-starved horse, in which the change and waste of tissue, and the consequent metamorphosis of the blood, would be very slight. That the difference must be small is obvious, when we consider that the whole course of the circulation may be accomplished in 25–30 seconds; that the plasma just conveyed to the tissues must every where propel the nutrient matter conveyed there by the preceding blood-wave, and that the tissues, every where saturated with nutrient plasma, only take up a supply proportioned to their consumption. The process of nutrition in the peripheral system is continuous and is supported by the liquid plasma with which all the tissues are surcharged; hence these tissues become the temporary recipients of far more nutrient matter than they can possibly consume, even as the rivulet contains infinitely more water than is necessary for the refreshment of the soil on its banks.

In both cases we found that the venous blood contained a larger proportion of solid constituents than the arterial; hence we infer that more water was removed by means of the kidneys, liver, and skin, than had been supplied to the blood by the nutrient fluids.

The quantity of fibrin in the venous blood in analysis 2 is greater than in the arterial blood, although, from our knowledge of the fact that fibrin is employed in the process of nutrition, we should have expected an opposite result. Hence we are led to attribute the excess of fibrin to the consumption of a large proportion of blood-corpuscles, a view which is confirmed by the circumstance that the venous blood in this instance is poorer in blood-corpuscles than the arterial.

The proportions are reversed in analysis 4, but whether from opposite causes or not I cannot decide. It is singular that in both instances the quantity of albumen is greater in the venous than in the arterial blood, since there can be no doubt that this constituent is consumed in the nutrition of the tissues, and that a portion of the changed plasma enters the lymphatics. I do not see how this increase can be accounted for, unless we assume, as I have previously done, that a portion of the globulin of the blood-corpuscles is converted into albumen during their metamorphosis.

In the present state of our knowledge regarding the metamorphosis of the blood, it is as difficult as it is hazardous to attempt to ex-

plain the various causes upon which the differences between venous and arterial blood are founded. There are, as I shall proceed to show, decided differences between the blood of the renal arteries and veins, and between the blood of the hepatic vein and of the vena portæ; and yet, as has been already shown, the differences between the blood of the aorta and of the vena cava are very immaterial and trifling. To produce this ultimate similarity, other changes (not yet heeded by the physiologist) must have largely contributed.

Properties of the blood of the vena portæ;—its comparison with arterial blood.

The blood of the vena portæ in horses (the only animals in which I have examined it) is darker than ordinary venous blood; the difference of the tint is, however, so slight as to be observable only upon actual comparison. It coagulates more slowly than ordinary arterial or venous blood; the clot is less firm, more of a gelatinous appearance, and falls to pieces if an attempt be made to lift it. I analyzed the blood of the vena portæ of the two horses already alluded to. If arterial, ordinary venous, and vena portæ blood are deprived of their fibrin by whipping, and are then allowed to stand, the blood-corpuscles subside in nearly equal times; but while they occupy little more than one half of the volume of arterial or ordinary venous blood, in portal blood they form nearly three-fourths of the whole volume.

In portal blood, after the lapse of several hours, a delicate glittering film was formed upon the surface of the serum, which, when seen under the microscope, was found to contain fat-globules; I could not, however, discover any lymph-granules either in the serum or amongst the blood-corpuscles. The arterial and ordinary venous blood, on the contrary, exhibited lymph-granules, but no fat-globules.

The blood of the vena portæ not only contains less fibrin than arterial or ordinary venous blood, but the qualities of that constituent are also different; it is not so consistent as ordinary fibrin, and does not separate into the firm globular little masses that are obtained by whipping arterial blood.

Our knowledge of the properties of this blood has been materially increased by the researches of Schultz.¹ The following are his principal conclusions: It is darker than ordinary venous blood, but the difference of tint is sometimes so slight, as to be hardly perceptible. It is darkest in fasting horses, but after a full meal it becomes brighter. These differences are more striking than those between arterial and venous blood. Common salt, nitre, atmospheric air, and even oxygen when shaken with the dark blood of the vena portæ, have scarcely any effect upon the colour, whereas venous blood would be changed to a brighter red by these reagents. If the blood of the vena portæ be not extremely dark, a slight change is perceptible.

¹ System der Cirkulation, p. 140.

If a portion of this black blood be treated with a quantity of common salt or nitre sufficient to prevent it from coagulating, coagulation may still be induced (although not until after several hours, and then very slightly) by the addition of water, while venous blood similarly treated coagulates in the course of five or ten minutes.

If the blood is very dark, it sometimes does not coagulate at all; if it is not very dark, it occasionally coagulates in the same time as ordinary venous blood; the clot, however, is very soft, and either entirely, or at least its lower surface, dissolves in the course of from twelve to twenty-four hours. Schultz farther observes, that after the blood has been whipt, the corpuscles sink very quickly; he ascribes this peculiarity to an excess of colouring matter attached to the capsules of the blood-corpuscles.

As the blood of the vena portæ that I analyzed was taken from the same two horses from which I obtained the arterial and venous blood, a fair comparison may be instituted with respect to their differences of constitution.

1000 parts contained:

	Analysis 1. Arterial blood.	Analysis 5. Blood of vena portæ.
Water	760.084	724.972
Solid residue	239.952	257.028
Fibrin	11.200	8.370
Fat	1.656	3.186
Albumen	78.880	92.400
Globulin	136.148	152.682
Hæmatin	4.827	6.600
Extractive matter and salts	6.960	11.680
100 parts of blood-corpuscles contained 3.4 of hæmatin.		100 parts of blood-corpuscles contained 4.1 of hæmatin.
	Analysis 3. Arterial blood.	Analysis 6. Blood of vena portæ.
Water	789.390	815.000
Solid residue	210.610	186.000
Fibrin	6.050	3.285
Fat	1.320	1.845
Albumen	113.100	92.250
Globulin	76.400	72.690
Hæmatin	3.640	3.900
Extractive matter and salts	10.000	11.632
100 parts of blood-corpuscles contained 4.7 of hæmatin.		100 parts of blood-corpuscles contained 5.3 of hæmatin.

It is only in four respects that the results obtained by a comparison of these two analyses of the blood of the vena portæ with arterial blood at all coincide: the former contains less fibrin, more fat, more extractive matter and salts than the latter, and lastly, the proportion of colouring matter to globulin is greater in the former.

In order to give a better idea of the relative proportions of the colouring matter, I shall quote another analysis of the blood of the vena portæ, which was made for the purpose of comparison with the blood of the hepatic vein.

In this analysis the colouring matter is separated into hæmatin and hæmaphæin. I obtained from 1000 parts:

	Analysis 7.	
Water	801·500	
Solid residue	198·500	
Fibrin	6·200	
Fat	2·700	
Albumen	90·000	
Globulin	75·690	
Hæmatin	3·400	
Hæmaphæin	1·600	
Extractive matter, with some hæmaphæin, } and with salts	14·400	

This blood was very rich in colouring matter, there being no less a proportion of it than 6·8 in 100 parts of blood-corpuscles, of which 4·5 were hæmatin and the remaining 2·3 hæmaphæin. In addition to this, the extractive matters retained a considerable quantity of hæmaphæin.

The circumstance that the blood of the vena portæ in analysis 6 contains less solid residue, and a smaller proportion both of albumen and blood-corpuscles than arterial blood, while the reverse is observed in analysis 5, need not excite much surprise when we remember that in analyses 3, 4, and 6, the blood was taken from an old, decrepit, starved animal.

Schultz¹ has made some very important observations on the relative constitution of the blood of the vena portæ, as contrasted with arterial and ordinary venous blood.

Solid Constituents.

The blood taken from the vena portæ of fasting horses gave, as a mean of three analyses, 16·90% of solid constituents, while arterial and venous blood gave 15·56% and 18·6% respectively: it contained therefore, (in this instance,) a greater proportion of solid constituents than arterial; a less proportion than venous blood. This proportion, 16·90%, is, however, less than is usually met with in arterial or venous blood.

The blood of the vena portæ of a horse fed with oats gave 20·3% of solid constituents, while the arterial and venous blood of the same animal gave 22·91% and 19·5% respectively. Here the solid constituents of the blood of the vena portæ bear an exactly opposite proportion to those of arterial and venous blood, for in this case they exceed those of arterial, and are less than those of venous blood.

The amount of the per-cent-age of the solid residue, although still deficient, approximates very nearly to the ordinary average.

My observations from analysis 5 are at variance with these remarks.

¹ Schultz's analyses of the portal blood would, in my opinion, have yielded more important results, both as regards the absolute and the comparative composition of the fluid, if he had determined all the constituents from the same identical blood. He appears to have used the blood of different animals for the determination of the different constituents. The absolute composition of the blood is assuredly different in different animals, but there are also relative differences depending on age, nutrition, and other circumstances.

Fibrin.

As an average of three analyses, $\cdot 32\%$ of fibrin was obtained from the blood of the vena portæ, while the proportions obtained from arterial and venous blood were $1\cdot 04\%$ and $1\cdot 09\%$ respectively. Hence it may be concluded that this blood is poorer in fibrin than either arterial or venous blood—a point which is confirmed by my own observations.

Albumen with salts, and blood-corpuscles.¹

The following results were obtained from his analyses:

	1.	2.	1.	2.	1.	2.
	Blood of vena portæ.		Arterial blood.		Venous blood.	
Albumen	-	$8\cdot16\%$	$9\cdot67\%$	$9\cdot86$	$11\cdot11\%$	$7\cdot96\%$
Blood-corpuscles	-	$8\cdot74\%$	$10\cdot53\%$	$4\cdot65\%$	$10\cdot21\%$	$9\cdot21\%$

The analyses 1 were made with the blood of fasting horses; the analyses 2 with the blood of horses after a recent meal of oats. Hence it follows that the blood of the vena portæ contains more blood-corpuscles and less albumen than arterial or venous blood. My own analyses do not exactly coincide with these remarks.

Fat.

The solid residue of the blood of the vena portæ gave, (as the mean of four analyses,) $1\cdot66\%$ of fat, while the corresponding proportions of fat in arterial and venous blood amounted to only $\cdot92\%$ and $\cdot83\%$. Hence it appears (and in this respect my own observations confirm those of Schultz) that this blood contains a larger proportion of fat than either arterial or venous blood. The albumen and the clot contain individually a larger quantity of fat in this than in ordinary blood. Schultz has observed a very striking difference between the quantity of fat contained in the fibrin of this and of arterial blood: the former yielded $10\cdot7\%$, while the latter gave only $2\cdot34\%$ of fat, which in the first case was brown and discoloured, in the latter was white and crystalline.

It follows from these remarks that there is no constancy in the deviations of the blood of the vena portæ from arterial or venous blood. The reason of the mutability of the composition of this blood is easily accounted for, if we consider the relation that the ramifications of the vena portæ bear to the digestive organs, and the absorbent power of the veins, as shown by the experiments of Magendie² Tiedemann and Gmelin.³

The rapid removal of water from the stomach can, moreover, only be explained by the agency of the vena portæ.

Hence it is evident, both from my own analyses and those of

¹ Schultz's method of analysis is described in note 1, p. 166.

² Précis élémentaire de Physiologie, par Magendie. Bruxelles, 1838, p. 398.

³ Müller's Physiologie des Menschen, vol. 1, p. 241.

Schultz, that the blood which is conveyed to the liver by the vena portæ differs in well-fed and in fasting animals.

When fluids, containing a smaller proportion of solid residue than ordinary blood, are absorbed by well-fed animals, we may naturally infer that the blood of the vena portæ will be more deficient in solid constituents than either arterial or venous blood. This view is confirmed by the observations of Schultz, excepting in the case of the horse that had been fed with oats shortly before its death, when a greater solid residue was left by this blood than by either the arterial or venous: in this instance, however, the residue was below the ordinary average of either venous or arterial blood. In fasting horses the residue is considerably below the average of ordinary blood.

The remarkably small quantity of fibrin that is invariably found in the blood of the vena portæ, as well as the large proportion of fat that is associated with the fibrin, is a point of considerable interest; as also the large proportion of blood-corpuscles observed by Schultz, and which occurred in rather a striking degree in my analysis 5.

It is of importance to trace the origin and development of these peculiarities, as we may thus be led to take clearer views of the functions of the liver and the preparation of the bile.

Schultz¹ attributes the source of all these peculiarities to the intestinal canal, to the lymphatic glands, and to the spleen.

The organization and vitality of the chyle, prepared in the intestinal canal, require (according to Schultz,) the co-operation of the plasma, which (being thus partially consumed) leaves a large proportion of blood-corpuscles, the majority of which appear to have been deprived of their nuclei by absorption, and to have been converted into empty capsules impregnated with colouring matter. To this is attributable the preponderance of the clot. The large quantity of fat is ascribed by Schultz to absorption of the chyle, and he considers that its dark colour is in some way connected with the metamorphosis of the colouring matter of the blood-corpuscles.

My own views with respect to the causes of the peculiar constitution of this species of blood differ, in a few immaterial points, from the ingenious explanation of Schultz.

There are two reasons for the very small quantity of fibrin in this blood. In the first place it may take up a quantity of fluid containing little or no fibrin, by which means the relative proportion of fibrin in a given quantity of blood must, of course, be diminished; and, secondly, it may be explained by the torpid motion in this part of the circulatory apparatus, and the deficiency of atmospheric oxygen: this latter reason may also account for some of its other peculiarities. In consequence of the deficiency of oxygen, the metamorphosis of the blood-corpuscles must be imperfect, deficient, and retarded, and the solution of the developed corpuscles will not be duly effected. To this cause we must ascribe not merely the dimi-

¹ Op. cit. p. 322.

nished quantity of fibrin, but the retarded solution, and the accumulation of the corpuscles, especially of such as are fully developed and abound in hæmaphæin, the consequent accumulation of that colouring substance in the plasma, and the necessarily dark tint of the serum, which possesses no means of throwing off that constituent.

The large proportion of fat is chiefly attributable to the fluids that are produced during the act of digestion, and which are conveyed into the portal vein. In examining this blood under the microscope, I have seen that it is rich in fat globules. The deep yellow, (or sometimes even brown) tinge of the fat is produced by hæmaphæin, which is very soluble in fat and cannot easily be extracted from it.

The fatty acids do not seem to undergo any change in the liver, for we find them, as well as the cholesterin of the blood, again in the bile. The cholesterin is particularly abundant, and is probably one of the products of the function of the liver.

Properties of the blood of the hepatic vein;—its comparison with the blood of the vena portæ.

I am not aware of any analysis of the blood of the hepatic vein having been made previously to my own.

Very important conclusions might doubtless be drawn respecting the constitution of the bile, by contrasting the analyses of the blood of the vena portæ with that of the hepatic vein, if it were not that we had to take into consideration with the former the blood of the hepatic artery with which it mixes in the capillary system of the liver.

As the contents of the hepatic vein are discharged into the vena cava inferior, immediately as it leaves the organ, it is no easy matter to obtain any considerable quantity of the blood in a pure and unmixed state.

Professor Gurlt has kindly assisted me in collecting specimens of this blood from horses.

The blood of the hepatic vein differs, in several respects, from any of the forms of blood that have been hitherto considered.

It appears to be darker than the blood of the vena portæ, (when contrasted with it,) but becomes of a somewhat brighter colour by continued stirring.

The separation of the fibrin is more difficult and tedious than from the blood of the vena portæ, and this constituent, when deposited on the rod, is possessed of very little consistence, is soft, gelatinous, and difficult to wash, a portion of it falling to pieces and being distributed through the water. The blood, after the removal of the fibrin by whipping, continues to manifest a tendency to gelatinize; the blood-corpuscles deposit themselves and form a dark coagulated clotted mass under the surface of the serum, from which no additional fibrin can be obtained by further stirring; and upon allowing it to rest, the same phenomena are again exhibited. On placing a

little of the blood, immediately after stirring, on a glass slip, the blood-corpuscles may be seen to collect into minute islets or spots; at least I observed this to occur in three specimens of this sort of blood that I analyzed at different times.

In one instance I found that the blood had actually coagulated, but slowly, after the removal of the fibrin by whipping, and upon renewed stirring I obtained a small quantity of stringy or coriaceous fibrin.

Microscopic analysis. On examining a specimen of this blood, not diluted with the ordinary solution of salt, the swollen corpuscles were observed moving about; some were distinct, some partly united with others; these gradually attached themselves to one another and formed irregular groups of various sizes, in which the outlines of the individual corpuscles could no longer be recognised. It appeared as if the corpuscles exuded a plastic matter, which might possibly be the cause of their adhering to each other.

On diluting the blood with a solution of hydrochlorate of ammonia, I once observed that the medium-sized corpuscles appeared studded with minute pearly beads, (*vide supra*, page 95.) The following observation which I made upon two occasions interested me extremely. I saw a great excess of small blood-corpuscles, about one fourth or one sixth of the ordinary size, whose true nature could only be recognised by their well-marked yellow colour, and by their passing from a spherical into a flattened form, when rotation was excited. The motions of these minute blood-corpuscles resembled those of Brown's molecules, and were much more active than those of the ordinary corpuscles in common blood.

The analysis of the blood of the hepatic vein gave in 1000 parts—

	Analysis 6. Blood of vena portæ.	Analysis 8. Blood of hepatic vein.
Water	- - -	815-000
Solid residue	- - -	185-000
Fibrin	- - -	3-285
Fat	- - -	1-845
Albumen	- - -	92-250
Globulin	- - -	72-690
Hæmatin	- - -	3-900
Extractive matters and salts	11-623	
		100 parts of blood-corpuscles contained 5-3 of hæmatin.
		100 parts of blood-corpuscles contained 5-2 of hæmatin.

The blood was taken from the starved horse, who supplied the matter for analyses 3 and 4.

	Analysis 9. Blood of vena portæ.	Analysis 10. Blood of hepatic vein.
Water	- - -	738-000
Solid residue	- - -	262-000
Fibrin	- - -	3-600
Fat	- - -	1-968
Albumen	- - -	114-636
Globulin	- - -	116-358
Hæmatin	- - -	4-920

	Analysis 9. Blood of vena portæ.	Analysis 10. Blood of hepatic vein.
Hæmaphæsin	1·467	1·040
Extractive matters and salts	16·236	17·160
100 parts of blood-corpuscles contained 5·4 of colouring matter, of which 4·2 were haematin and 1·2 hæma- phæsin.		100 parts of blood-corpuscles contained 4·8 of colouring matter, of which 3·9 were haematin and 0·9 hæma- phæsin.

From these analyses we deduce the following conclusions. The blood of the hepatic vein is richer in solid constituents than that of the vena portæ, and consequently than either arterial or ordinary venous blood; it contains less fibrin, fat, globulin, and colouring matter, than the blood of the vena portæ; the ratio of the colouring matter to the globulin is smaller, and the quantity of albumen larger in the former than in the latter form of blood.

In consequence of the admixture of the blood of the hepatic artery with that of the vena portæ in the capillary system surrounding the biliary ducts, and of the catalytic influence of the cells of the liver in the formation and secretion of bile, it is impossible for us to ascertain the relative parts which these two distinct forms of blood play in the production of this important secretion, or to state with certainty which constituents are drawn from the contents of the hepatic artery and which from those of the vena portæ, or how the withdrawal of them is effected.

These analyses are nevertheless of great importance, since they show that the blood-corpuscles are actively engaged in the secretion of the bile, a view which corresponds with and tends to explain other phenomena connected with this secretion. They show that the blood of the hepatic vein contains more albumen and less globulin, or (which is much the same thing) blood-corpuscles, than that of the vena portæ. These differences favour the hypothesis that the corpuscles (or, at least, their principal constituents, the globulin,) have a greater share in the formation of the bile in the peripheral system of the liver than the albumen, the principal constituent of the plasma.

Another corroborative circumstance is the small amount of colouring matter in the blood of the hepatic vein, from which we infer that some of it has been consumed in the formation of the bile, a view which accounts, with more probability, for the origin of its colour than the supposition that it is produced from a portion of the plasma.¹

If the liver were supplied with blood from the vena portæ alone, there could be hardly a doubt entertained with regard to the correctness of my hypothesis; the influence of the blood of the hepatic artery must not, however, be overlooked. If, for instance, the blood of the hepatic artery contained a much larger proportion of albumen and a smaller quantity of blood-corpuscles than the blood of the vena

¹ [This view is corroborated by Mulder, who observes that if the blood-corpuscles undergo a metamorphic change prior to their development into living tissue, the products of the decomposition of the haematin may be probably traced in the *bilifluvin* of the bile. (Versuch einer allgemeinen physiologischen Chemie, p. 358.)]

portæ, the mixture of these would produce a fluid similar in constitution to the blood of the hepatic vein. But, upon comparing the blood of the vena portæ with that of the hepatic artery, no such proportions, as those we have assumed, are observable. It is true that a mixture of the two bloods in a badly fed animal would contain more albumen, but, at the same time, more blood-corpuscles than the blood of the vena portæ (see Analyses 3 and 6;) and in the reverse case (see Analyses 1 and 5) the mixture would contain fewer corpuscles, but, at the same time, less albumen, than the blood of the vena portæ.

It is impossible to account for so large an amount of albumen in the blood of the hepatic vein, if we consider the quantity of bile which is secreted by the healthy liver, and attribute its formation to the elements of the plasma alone; whereas, if we consider the bile to be formed at the expense of the blood-corpuscles, the peculiarities in the blood of the hepatic vein are at once accounted for.

In addition to the separation of the bile, the liver effects a further change in the blood by drawing from that fluid the sources of its own nutrition. These two processes merge into one, which may be regarded as the product of the development of the hepatic cells. The formation and secretion of such a complicated fluid as the bile, by the action of the hepatic cells on the plasma, may be dependent on various causes. The entire structure of an organ must necessarily correspond with its functions, and with every variety of internal organization there will be a corresponding variation in the secretion. The action of the hepatic cells on the plasma is different from that of the renal or other glandular cells, in consequence of the difference of their chemical action on the blood. The nerves also seem to influence the secretions.

Further, since the plasma has been modified in its progress through the liver by the solution of a large number of blood-corpuscles, a corresponding new product must be evolved from it by the hepatic cells. I have previously stated that the development, and especially the ultimate solution of the blood-corpuscles may occur in all parts of the peripheral system, if a sufficient supply of oxygen be present. I have shown that a large quantity of fully developed corpuscles accumulates in the blood of the vena portæ, in consequence of its torpid motion and the want of a due supply of oxygen; if this blood mixes in the capillaries with the well-oxygenized blood of the hepatic artery, it is not difficult to conceive that a proportionably larger quantity of blood-corpuscles is thus dissolved in a given time than at many other parts of the peripheral system, that the plasma may thus become changed, and that the product of the general action of the hepatic cells may be different.

It is well known that the liver is one of the most active organs of the animal economy. Even in the embryo, the development of its cells is wonderfully abundant, as has been shown by Reichert. In the adult, activity of the liver is exhibited by the increased secretion of the bile during digestion. The activity of an organ is represented

by the integral of the activity of its cells; and the increased activity of the cells is intimately connected with the facility of evolution and revolution. If, then, in consequence of the activity of the liver as a secreting organ, a large number of cells are consumed, it follows that a proportionably large number must be reproduced; and we can thus explain the apparently inconsistent phenomena of the blood of the hepatic vein containing less fibrin than that of the vena portæ, by the supposition that, although a large quantity of blood-corpuscles is consumed by the liver, the fibrin of the plasma supplies the materials for the formation of cytotlasts for new cells.

All the other differences that are observable between the composition of the blood of the hepatic vein and of the vena portæ may be accounted for by paying a little attention to the nature of the bile.

The bile contains a smaller proportion of solid constituents than the blood; hence it is obvious that the blood, previously to the separation of the bile (*i. e.* the blood of the vena portæ) must contain a smaller proportion of solid constituents than after this change has been effected (*i. e.* the blood of the hepatic vein.)

The blood of the vena portæ contains more colouring matter, both haematin and haemaphæin, than that of the hepatic vein. It is impossible to decide with certainty upon the manner in which these colouring substances are consumed in the liver, as we are still deficient in correct ultimate analyses of biliphæin and haemaphæin; we may, however, safely conclude that the biliphæin is produced by the metamorphosis of the colouring matter of the blood.

Properties of the blood of the renal veins;—its comparison with the blood of the aorta.

The blood of the renal veins was drawn from a horse simultaneously with the aortic blood: it was found, however, upon opening the body of the horse, bled to death, that the renal veins contained so small a quantity of blood that Professor Gurlt was unable to collect from them more than about 50 grains.

The blood obtained in this manner was visibly darker than the aortic blood. I stirred it for a considerable time with a rod, but could obtain no fibrin; on leaving it to stand, it became gelatinous, and resembled the blood of the hepatic vein after similar treatment.

Microscopic analysis. Upon comparing the two sorts of blood under the microscope, the only perceptible differences were the following: In the unmixed blood of the renal veins the corpuscles united themselves into islets and amorphous groups, in which the individual globules could not be traced. Upon mixing some of this blood with a solution of salt, a larger quantity of small and middle-sized corpuscles were observed than in the aortic blood when similarly treated. The proportion, however, of the small corpuscles to the large ones was not so striking as in the blood of the hepatic vein. (Vide supra, p. 175.)

In consequence of the small quantity of material, I resolved to determine only the most important of the constituents. I made an accurate estimate of the proportions of water and albumen, but was prevented by illness from ascertaining the quantities of globulin and haematin.

1000 parts of blood contained:

	Analysis 11. Aortic blood.	Analysis 12. Blood of renal vein.
Water	790-000	778-000
Solid residue	210-000	222-000
Fibrin	8-200	?
Albumen	90-300	99-230

From these analyses it appears that the blood of the renal vein is more abundant in solid constituents and in albumen than the aortic blood, but that it contains less fibrin and fewer blood-corpuscles.

The two latter inferences, respecting the quantity of fibrin and of blood-corpuscles in the blood of the renal vein, cannot be drawn from the analyses in the same certain manner as in the comparative analyses of the blood of the hepatic vein and of the vena portæ.

Although I cannot believe that this blood is entirely devoid of separable fibrin, it certainly contains less fibrin than arterial blood. In fact, it is more than probable that the quantity of fibrin which is formed during the course of the blood through the renal capillary system, where oxygen is taken up and not again supplied, does not exceed the quantity consumed. Although no determination of the haematin and globulin was instituted, we may infer, analogically, from our former analyses, and from the necessary reciprocating proportions of the two principal constituents of the blood, that less haemato-globulin exists in the blood of the renal veins than in that of the aorta. If the albumen in each be estimated in regard to equal quantities of the solid residue, the albumen in the aortic blood will be found to be to that in the blood of the renal vein in the ratio of 425 to 446. The quantities of haemato-globulin will therefore be in an opposite ratio.

These results throw considerable light upon the changes which the blood undergoes in the kidneys. It loses a certain quantity of water, which is accounted for by the urine. Hence this blood contains less water than the aortic blood.

Urea appears to be formed from the corpuscles, under the co-operating influence of the plasma and oxygen of the blood, rather than from the albumen, which preponderates in the blood of the renal veins the same as in the hepatic vein. It cannot be *positively asserted* that the observations which were made regarding the trifling amount of fibrin in the blood of the hepatic vein, as compared with that in the blood of the vena portæ, here hold good, but there are many reasons in favour of such an analogous view.

It is highly probable that the activity of the excreting powers of the kidney is due to the activity of the organ itself, as has been al-

ready observed with regard to the liver, and that this activity corresponds with the energetic evolution and revolution of renal cells.

That the kidneys do not separate bile, but urea, uric acid, and salts, is due partly to the chemical constitution of the renal cells and to the peculiarly directed co-operation of the nerves of these organs, and partly, perhaps, to the composition of the blood itself, which differs from that which supplies the liver.

The separation of the water is caused by the peculiar internal structure of the organ; it cannot be regarded as a product of the development of the cells, or of the metabolic power of the cells acting on the plasma; but the water is separated in much the same manner as the various gases of the blood are removed by the lungs.

But whether the salts which are separated by the kidneys, the combinations of chlorine, and of phosphoric sulphuric and lactic acids, are, so to speak, mechanically carried away in the water in which they are held in solution, and whether ~~it~~ ^{they} form the textures of the kidney, or whether their separation is to be regarded as a true secretion of the renal cells, due to their organized development, is a point which I have no means of ascertaining. An accurate analysis of the kidneys would soon show whether the salts which have been mentioned do or do not belong to the constitution of the renal cells, a point which the analysis of Berzelius has left undecided. These salts, most of which pre-exist in the blood, at all events find their way into the renal cells, and either are or are not connected with their peculiar vital development. The former is far the more probable; and in that case the secretion of the salts would not be a mere mechanical act, but would be due to organic causes.

The kidneys separate haemaphæin from the colouring matter produced by the metamorphosis of the blood-corpuscles, and the proportion in which they separate it is larger than the proportion contained in the plasma, a circumstance which is obvious from the colour of the urine being generally deeper than that of the liquor sanguinis. Hence it is very probable that a portion of the colouring matter is formed by the metamorphosis of the corpuscles in the peripheral system of the kidney. The kidneys likewise separate another colouring matter, uroerythrin; in a normal state, only in a slight proportion, but in certain pathological conditions, in a comparatively large quantity. Uroerythrin, in all probability, owes its origin to the haematin of the blood-corpuscles. As the proportions of uric acid and of uroerythrin to urea are very small in normal urine, but are much increased in certain pathological conditions, we must infer that, in these latter cases, the blood undergoes some peculiar change.

Comparison of the venous blood with the blood of the capillaries.

It is well known that blood taken from the body by scarification does not materially differ in its physical properties from venous blood; it takes about an equal time to coagulate, and separates into

clot and serum. The blood which flows from leech-bites is also similar to venous blood. From comparative analyses of venous blood and blood taken by leeches or cupping, Dr. Pallas¹ concludes that the (so termed) capillary blood is richer in solid and coagulable constituents than either venous or arterial blood.

The ratios are represented by the following numbers:

$$\begin{array}{ll} 2\cdot550 : 3\cdot100 & \text{and} \\ 2\cdot550 : 2\cdot630 & \end{array}$$

Denis² contradicts these statements; he observes that the blood of the capillaries, when taken by cupping, is of a bright red colour and very plastic if it is taken from the neighbourhood of a large artery, but that it is dark and proportionally less plastic when drawn from the vicinity of large venous trunks; so that its characters always present a certain degree of similarity to either arterial or venous blood. Denis analyzed blood drawn from the arm of a man aged 70, and blood taken by cupping from the left side of the thorax of the same individual, and compared the results. 1000 parts contained:

	Blood from the arm.	Blood obtained by cupping.
Water	790·0	790·0
Fibrin	2·7	2·9
Albumen	56·0	54·0
Hematin	131·6	133·4
Oxide of iron	0·7	0·7
Phosphorized fat	8·0	8·2
Cruorin	1·1	1·0
Carbonate of soda	1·0	1·0
Chloride of sodium	4·0	4·0
Chloride of potassium	2·1	2·0
Carbonate of lime	1·3	1·3
Phosphates of lime and magnesia	0·5	0·5

Or,

Water	790·0	790·0
Blood-corpuscles	132·3	134·1
Solid residue of serum	77·7	75·9

Denis also analyzed the blood of a girl, aged 27, in a similar manner, and obtained corresponding results from both forms of blood. (Recherches, pp. 152, 153, and 250.)

REVIEW OF THE MODIFICATIONS AND CHANGES THAT THE BLOOD UNDERGOES IN THE COURSE OF THE CIRCULATION.

Having in the previous section given my views respecting the probable changes that the blood undergoes in the course of the circulation, founded partly on numerous analyses of that fluid, and partly on conclusions deduced from the necessary connexion that exists between the phenomena of secretion and of metamorphosis; and having also endeavoured to explain the variations that occur in the blood of the same individual, through the influence of nutrition and the secreting organs (as the liver and kidneys,) I beg once more to call the attention of the reader to the subject under consideration.

¹ Journal de Chimie Médicale, Oct. 1828.

² Recherches, p. 72.

My views regarding the formation of the products of secretion from the changes that the blood undergoes in the organism require a more searching investigation before confidence can be placed in them. There is nothing improbable in the supposition that the blood is changed in the manner that I have assumed; I can as easily conceive that the urea and bilin are formed by the mutual action of the blood-corpuscles and the liquor sanguinis, as that their origin is dependent upon the liquor sanguinis alone; but for reasons already communicated, there is a greater degree of probability in the idea that these substances are produced by the metamorphosis of the blood-corpuscles. These reasons are founded more on the intimate connexion that exists between the products of secretion, change of matter and blood, and on the mutual adaptation and principle of compensation in the organism of the animal body, than on the physical and chemical "momentum" of the circulation and of secretion; and the question we have now to consider is, whether in the latter there is not something directly opposed to our views respecting the metamorphosis of the blood.

Before proceeding to these investigations, I must in the first place revert to some of the points connected with this metamorphic action.

The first and principal object of the blood is the nutrition of the organism, and for this purpose the circulating fluid is modified and consumed in the peripheral system. We have conjectured that the extractive matters of the blood which are removed by the kidneys are thus formed. The constant modification and consumption of blood dependent on the act of nutrition render the supply of fresh nutrient fluid, and the removal of effete matter, indispensably necessary, since a proper constitution of the blood is requisite for the due performance of the function of nutrition. The effete matters are replaced by chyle mixed with lymph; and this fluid must of necessity be converted into blood, as otherwise the blood would soon consist entirely of chyle. The change is effected by the formation of young blood corpuscles, (an act which is accompanied by the consumption of chyle-, lymph-, and oil-corpuscles,) and by the fibrin of the chyle becoming more plastic; all the other fluid constituents of the chyle are similar to those of the liquor sanguinis, except that there is an excess of water and of extractive matters in the former. If therefore we suppose a continuous formation of blood-corpuscles, the necessity for their consumption must be sufficiently obvious. I have assumed that fibrin is formed as a consequence of this consumption, and that this newly-formed fibrin supplies the place of that which is employed for the purposes of nutrition in the peripheral vascular system. I have also shown, (page 139,) that there is no difficulty in the idea of the formation of albumen; and lastly, I attempted to show that, in all probability, urea, uric acid, and bilin are formed as a consequence of this consumption of the blood-corpuscles. For these substances must necessarily be formed as products of the changes which the constituents of the blood undergo in the circulation, and are not (as

observations on starved and emaciated individuals show us) a consequence of the changes which the circulating fluid undergoes during the nutrition of the tissues, but are dependent on the metamorphic action that is produced by the respiratory process. It is principally the blood-corpuscles, (as I have endeavoured to show, in page 133,) that are connected with the consumption of oxygen; and when we reflect that this change in the corpuscles must take place under similar conditions in animals both high and low in the scale of development, we can understand how it is that urea, uric acid, and bilin occur in the renal and hepatic secretions of animals of nearly every form of structure, and under such varying phases of existence.

I will now proceed *seriatim* with the objections that may be urged against my views respecting the metamorphosis of the blood.

Analyses of the urine show us that it contains a greater amount of urea and uric acid than of extractive matters; assuming that the former substances, and the bilin, are products of the metamorphosis of the blood-corpuscles, and that the latter are the products of the change that the plasma undergoes in the nutrition of the peripheral system, the mass of the former is greater than the mass of the latter. If, moreover, a portion of the extractive matter is in reality not removed by the kidneys, but is, as I have already suggested, in page 129, again adapted in the circulation to the purposes of nutrition, (serving probably for the cytoplasm of the cells of the cartilaginous and gelatinous tissues,) then the separation of so considerable a quantity of the product of the metamorphosis of the blood-corpuscles ought still to surprise us, if its only purpose were to supply the fibrin, and possibly a part of the consumed albumen in the plasma.

It can, however, be easily shown that another and a much more important final result must be considered in the consumption of the blood-corpuscles. For if, as I have shown, in page 133, the blood-corpuscles are principally concerned in the consumption of the atmospheric oxygen, then it is clear that the greater part of the carbon which is exhaled from the lungs as carbonic acid, must originate from them, and the source of animal heat would thus be chiefly attributable to the metamorphosis of the blood-corpuscles. Consequently, the chemical modifications of the blood-corpuscles are of at least as much importance as the act of nutrition in the peripheral system carried on by the agency of the plasma, inasmuch as they are subservient to the most essential and indispensable requisite for animal life. The other purposes of the corpuscles appear also to be subservient to this great end.

If the blood-corpuscles (from the period of their development up to their final solution) convert as large a quantity of carbon as is generally assumed, into carbonic acid, in order to maintain a proper degree of temperature, then we cannot be astonished at the amount of the products of secretion of the kidneys and liver, which we have assumed to be consequent on the metamorphosis of the blood-corpuscles; for since the animal matters undergo a chemical change by

the elimination of the carbon, the products which are then formed must be removed, in order that the blood may retain its normal composition.

In opposition to the assertion that the urea, uric acid, and bilin are products of the metamorphosis of the blood-corpuscles, it may be urged that the daily amount of these secretions involves a larger daily consumption of blood corpuscles than appears to be consistent with the rate of their reproduction, as far at least as our knowledge of the act of formation of the corpuscles would lead us to infer.

I have mentioned, in page 133, that the blood-corpuscles are to be regarded as cells, whose development must be considered as perfectly analogous with the development of other cells. In absorbing from the plasma the substances requisite for their nutrition, and in rejecting the products that must be consequent upon the act of absorption, they obviously exert a modifying influence on that fluid. The blood corpuscles do not, however, find their way into the circulating fluid in a matured form, but their cytoplasm enter it as germs of the future corpuscles, and require the assistance of the atmospheric oxygen to attain their perfect development. The only hypothesis we can frame regarding the primary formation of the blood-corpuscles is, that they are produced from the plasma, that their entire development and increase of bulk is due to the reciprocal action of the young blood-corpuscular cells and plasma on each other at the expense of the latter, and that up to the moment when the blood-corpuscles cease to discharge their functions as independent organisms in the circulation, every change that occurs in them must be accompanied by a simultaneous alteration in their cytoplasm, the plasma.

It may further be urged that, in order to account for the formation and secretion of urea, uric acid, and bilin, there is no necessity for the assumption that there is a metamorphosis of the blood-corpuscles. These substances might as easily have been formed in the process of chylification, or during the conversion of the chyle into blood, or from the albumen, instead of from the corpuscles.

I have already mentioned that it is by no means probable that these products of secretion are formed in the act of nutrition, since they are produced in fasting persons, and even when nearly all the soft tissues are wasted away.

We do not, however, intend to assert that nutrition exercises no influence over these products, or that the peculiar structure of each secreting organ is not to be considered. Nevertheless I cannot agree with certain physiologists who maintain that in granivorous animals, sugar formed in the chyle is the cause of the carbonic acid evolved from the lungs, or that urea, uric acid, and bilin are formed solely from the albumen, and that the blood-corpuscles take no part in this action; for the uniform and simultaneous formation of carbonic acid, urea, uric acid and bilin, in animals whose food is so varied, and whose habits and conditions of life are so diversified, renders it probable that these substances are simultaneously formed, as a conse-

quence of one and the same metamorphic act. On the other hand, we must not omit to notice that the occurrence of the non-nitrogenous hippuric acid in the ruminantia, the excessive production of uric acid accompanied frequently with a total absence of urea in birds and amphibia, and the inverse ratio in which these substances occur in man, monkeys, &c., as likewise the different chemical relations of the bile in fishes and amphibia, point out the influence of nutrition and of the organization in general on these secretions. What is the ultimate purpose of the blood-corpuscles in the organism if they do not participate in the formation of these products, and if they experience no real material change? The idea that the nutrition of the tissues is accomplished by the aggregation of blood-corpuscles is now abandoned, and the supposition that these molecules exert a vitalizing influence on the organized tissues is perfectly unintelligible. I can form no conception of a blood-corpuscle that is not undergoing a continuous material change, and I regard this change as the ultimate object of its existence.

Daily experience shows us that the fluids which are secreted by the principal glands take their origin from the blood: the question then arises whether these secretions exist in the blood itself, that is to say, whether the blood which enters a secreting organ, as the kidney or liver, indicates a difference of composition as it leaves that organ. At first sight we should doubtless answer this question in the affirmative; but taking into consideration the rapidity of the circulation, and the short space of time in which the same blood is supposed to remain in an organ, it is obvious that the detection of the changes in the blood, due to the removal of the secretions, will be a task, if not absolutely impossible, at least extremely difficult.

The question whether the blood of the same individual possesses any traceable differences, is most intimately connected with the physico-chemical "momentum" of the circulation; although sufficient facts and experiments are still wanting to enable the point to be decisively settled, I believe, from an estimate of all that is at present known on the subject, that we are warranted in the assumption that there does exist a difference in the blood of one and the same individual.

According to Hering's experiments,¹ (in which he injected ferrocyanide of potassium into the veins of horses,) the blood performs the circuit of the body in from 20 to 30 seconds. Several authorities are opposed to this statement. It is evident that the blood, as it issues from the heart, proceeds in smaller and larger circles; the smallest are those which it describes through the heart itself and the lungs, the larger are those through the extremities, and it must require different times to go over these different spaces, and besides this, its course is differently impeded in the capillary system of the different organs. Thus one portion of the blood may frequently pass through

¹ *Treviranus Zeitschrift für Physiologie*, 1832, p. 85.

the heart and lungs, while another portion has only made one complete circuit, and traces of the injected ferrocyanide of potassium which permeates uniformly the whole mass of the blood, may therefore be found after a short time in parts of the system remote from the heart, which have not gone the perfect circuit through the heart, lungs, and all the organs. This appears to be very evident from the fact that some of those salts which are supposed to be rapidly eliminated by the kidneys, may be detected for a considerable period in the blood. Thus I have observed,¹ that when iodide of potassium was taken at four o'clock in the afternoon, its presence was traceable in the urine till nine the next morning; and Hering² found ferrocyanide of potassium in the urine of a horse two days after it had been injected. Hence the whole mass of the blood occupies a considerable time in passing through the renal arteries, or else the kidneys do not remove all the foreign constituents from the blood that passes through them.

Others have calculated the rapidity of the circulation by the quantity of blood projected by the heart at each systole. Reckoning this quantity at from 1 to 2 ounces, and the whole amount of blood in the human body at 30 pounds, it would take from 3 to 7 minutes (assuming the pulse to be 75 in the minute) for all this blood to pass through the heart. Since, however, the blood in the smaller circles passes more frequently through the heart in a given time than the blood in the larger circles, and since it is variously impeded and delayed in the different organs, we must not consider that the absolute mass of the blood of the whole body is represented by the identical 30 pounds which pass through the heart in from 3 to 7 minutes. The quantity of blood in an adult has likewise never been accurately determined. Hales places it at 25 pounds; the maximum is, however, calculated to amount to 30 pounds; and when we consider the extremely large quantity of blood that is retained in the capillary vessels, this estimate is probably too low.

That the rapidity with which the blood circulates varies inversely with the distance from the heart is an established fact. In the capillary system its progress is the most torpid. Omitting the consideration of the various mechanical impediments that meet the blood in the capillaries, it must be remembered that, if the blood is the real nutrient fluid of the body, there must be a necessary attraction between it and the organs it has to nourish. The blood in the capillary network permeates the tissues, or (to speak more correctly) the cells of the tissues attract from the blood their proper nutriment. It is clear that this must delay the course of the blood in the peripheral system, to what amount it is impossible to say, but in all probability the delay will vary directly with the intensity of the action between the blood and the tissues, and with the amount of the change of matter. The greatest delay will most probably occur in the kidneys

¹ Simon, *Die Frauenmilch nach ihrem chemischen und physiologischen Verhalten*. Berlin, 1838, p. 75.

² Op. cit. p. 96.

and in the liver, since they afford the largest amount of secreted matters. Even if the amount of the secretions did not indicate a heightened cellular activity, it would be sufficiently proved by the structure of the organs themselves, for they are permeated by such an extremely abundant and dense capillary network, and such very delicate venous twigs closely encircle their excretory ducts, that the tissue is brought in contact with the blood at every point and in every direction.

The chemical constitution of these organs is likewise so peculiar, that we might infer that the cells would exert a particular influence; for the muscular tissue, serous membrane, lung, &c., when triturated with water, yield little else than some of the constituents of the blood from the capillary vessels, while the liver and kidneys by trituration yield a pappy mass, which is for the most part soluble in water, contains much fat in a state of suspension, and leaves only a small amount of solid residue (18·9% in the liver, and, according to Berzelius, even less in the kidneys,) consisting of shreds of vessels and membranes.

From the observations already made, we may infer that the blood undergoes a much more rapid metamorphosis in the kidneys and liver than in the tissues of the muscles, bones, &c. If it were possible to determine the time during which the same blood remains in these organs, then we might decide with some degree of certainty whether the blood which emerges from them differs in its composition from that which enters them. We have seen that there are reasons for assuming that the circulation is delayed in these organs. If we suppose, with Haller,¹ that the eleventh part of the whole blood passes through the kidneys, and that, consequently, at each systole of the heart four scruples are driven into them, then, assuming that the kidneys contain from four to six ounces of blood, and that the rapidity of the circulation in them is the same as in the aorta, the same blood will remain in these organs for about one third or one half of a minute. But taking into consideration the various facts that we have adverted to regarding the impeded circulation in these organs, we can scarcely doubt that the blood is detained in them for a very considerable period. According to a calculation made by Keil, and quoted by Hales in his 'Medical Statics,' the blood remains in the kidneys for several hours.

R. Wagner² measured the rapidity with which a blood-corpuscle moves in the capillary system, and found that it traversed a course of from 12 to 15 lines in the course of a minute. If the motion of the corpuscles and of the blood is supposed to be equal, and if the blood progresses in the large vascular trunks at the rate of eight inches in one second, and consequently 480 inches in one minute, then the rapidity of the blood in the larger trunks will be to the rapidity in the capillaries in the ratio of from 480—384: 1; a calcula-

¹ *Elem. Phys.*, vol. 2, p. 467.

² *Lehrbuch der Physiologie*, part 2, p. 193.

tion tending to show that the blood remains in the kidneys for a space of from one to two hours.

To this it may be objected that the phenomena of resorption are opposed to these results, and that if the renal veins convey away as much blood as is conducted to the kidneys by the renal arteries, this protracted delay would be impossible. We cannot, however, determine with certainty the amount of blood that enters the kidneys, for there is no necessity that the whole mass of the blood should flow through them as through the lungs; moreover, only one branch of the aorta enters this viscous, and while the tendency of the blood is to flow in the direction in which it meets with the least opposition, there is, perhaps, no organ in the whole body that offers a greater resistance than the kidney. The chemical change that the blood undergoes in the kidneys must likewise be much more rapid than in the capillary vessels of many other tissues, since, in addition to the large amount of secretion that they yield, a portion of the consumed blood is carried away by the lymphatic vessels.

Let us now endeavour to ascertain how long it would be necessary for the blood to remain in the kidney, in order that the contents of the renal veins should exhibit chemical peculiarities dependent on the action of the gland. Assuming that a healthy man secretes about 40 ounces of urine in 24 hours, and that the change dependent on the secretion of 10 ounces of urine from 1000 ounces of blood may be detected by the changed proportion of the water, then, omitting all consideration of the lymphatic vessels, 4000 ounces of blood would pass through the kidney in 24 hours, in order to separate 40 ounces of urine. According to this calculation, 250 pounds of blood would pass through the kidneys in 24 hours, about 10 pounds in one hour, and 1 pound in six minutes; and assuming that both kidneys contain six ounces of blood, this blood must be retained in them for at least two minutes. This period is much shorter than those deduced by Keil and Wagner, in which it amounts to hours.

I think we may fairly conclude, from the preceding observations, that the changes which the blood undergoes in its composition while passing through the kidneys and liver, are appreciable; for if we have shown the probability of the correctness of the statement in the case of the kidneys, there can be no question that it is true in the case of the liver, which is every where permeated by the torpidly circulating blood of the vena portæ.

On the absolute composition of healthy venous blood.

It cannot be doubted but that the blood of different individuals in a state of perfect health will exhibit differences of composition, and that it would be the merest chance if the composition of the blood of two persons were found to be precisely the same. The circumstances capable of inducing a change in the composition of

the blood are very numerous. Different methods of life, and various modes of nourishment, might cause such changes; but, independently of these external influences, there are others connected with the individual which must modify, to a greater or lesser degree, the composition of the blood, as, for instance, the influences of sex, age and temperament.

It is extremely difficult to determine a formula for the composition of normal blood that would serve as a standard, by comparison with which we might detect absolute deviations in other forms and specimens of blood, on account of the variable nature of the fluid, changing even, in the same individual at different periods of the day, and in accordance with the food that has been taken.

In a medical point of view, the composition of venous blood is the most interesting, because it is from the veins that blood is almost always taken in disease, and because venous blood can naturally only be compared with venous blood for the purpose of ascertaining any deviations that may occur.

Before attempting to give a decided opinion on the normal composition of venous blood, it would be requisite that numerous accurate analyses of the blood of healthy males and females of different ages should be instituted. Possibly we should also regard the influence of their various modes of life, and (if we ascribe any influence to the circumstance) of their temperaments.

Experiments of this nature are still wanted, and the contributions hitherto made with that object by no means meet the exigencies of the case. Many difficulties present themselves in such an investigation.

It is not an easy matter to select individuals from whose state of health we can infer that the composition of the blood closely approximates to the normal standard, and after the selection is made it is still harder to convince them of the advantage or necessity of venesection in their own cases.

I was obliged to content myself with two such analyses, one of the blood of a young man, the other of an unmarried female.

Analysis 13. N—, aged 17 years, a servant, of sanguineous temperament, nearly full grown and properly developed, chest well arched, respiratory and digestive organs healthy, countenance florid and blooming, was bled from the arm. The blood was apparently rather brighter than usual, and when allowed to stand, separated into a bright red, uniformly coloured, copious, and properly consistent clot, and a clear bright yellow serum.

A portion of the blood was whipped as soon as it was drawn, and the analysis was conducted in accordance with my ordinary plan.

1000 parts contained:

Water	:	:	:	:	:	791.900
Solid residue	:	:	:	:	:	208.100
Fibrin	:	:	:	:	:	2.011

Fat	-	-	-	-	-	-	1.978
Albumen	-	-	-	-	-	-	75.500
Globulin	-	-	-	-	-	-	105.165
Hæmatin	-	-	-	-	-	-	7.181
Extractive matter and salts	-	-	-	-	-	-	14.174

100 parts of blood-corpuscles contained 6.3 of hæmatin and hæmaphæin.

Analysis 14. S—, a servant girl, aged 28 years; temperament rather phlegmatic than sanguineous; tall, strong, and vigorous; countenance healthy; digestion good; had menstruated a fortnight before. The blood from the arm appeared rather dark, and on being left to itself separated into a considerable clot, and bright, clear yellow serum.

1000 parts of this blood contained:

Water	-	-	-	-	-	-	798.656
Solid residue	-	-	-	-	-	-	201.344
Fibrin	-	-	-	-	-	-	2.208
Fat	-	-	-	-	-	-	2713
Albumen	-	-	-	-	-	-	77.610
Globulin	-	-	-	-	-	-	100.890
Hæmatin	-	-	-	-	-	-	5.237
Extractive matter and salts	-	-	-	-	-	-	9.950

100 parts of blood-corpuscles contained 5.2 of hæmatin and hæmaphæin.

These two analyses indicate a great similarity between the blood in both sexes in a state of health; and if, in the absence of other and better experiments, we venture to take these as descriptive of the composition of normal blood, we may give its leading features in the following terms. *It contains about 20% of solid constituents; not much more than 0.2% of fibrin, and about an equal quantity of fat; the blood corpuscles considerably exceed the albumen in quantity, and contain about 5% or 6% of colouring matter.*

Lecanu, although his method of analyzing the blood is different, obtains similar results. He has given in his Thesis,¹ ten analyses of healthy venous blood, which I shall here communicate.

Age.	Water.	Solid residue.	Albumen.	Blood-corpuscles.	Extractive matter, salts, and colouring matter.
45	780.210	219.790	72.970	132.820	14.000
26	790.900	209.100	71.560	129.670	8.670
36	782.271	217.729	66.090	141.290	10.349
38	783.890	216.109	67.890	148.450	9.770
48	805.263	194.757	65.123	117.484	12.120
62	801.871	198.129	65.389	121.640	11.100
32	785.881	214.119	64.790	139.129	10.200
26	778.625	221.375	62.949	146.685	11.541
30	788.323	211.677	71.061	131.688	8.928
34	795.870	204.130	78.120	115.850	10.010

The mean of these analyses would give—

37	789.320	210.680	68.059	132.490	10.688
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From these analyses we therefore obtain about 21% of solid residue, and a larger proportion of blood-corpuscles than albumen. Lecanu assigns to the fibrin rather a larger proportion than I do, viz. 29%.

¹ *Etudes chimiques sur le Sang humain, etc.*, p. 62.

The analyses of Denis, (although from the very different manner in which they were conducted, their results cannot be very well compared with mine,) upon the whole, support my statements with regard to the proportions in which the most important constituents occur.

I shall give some of his analyses in a condensed form, reducing them to the relative proportions of water, solid residue, fibrin, blood-corpuscles, and albumen.

The venous blood of healthy men contained in 1000 parts:

No. in Denis's work.	Age.	Water.	Solid residue.	Fibrin.	Albumen.	Blood-corpuscles.
46	21	733.0	267.0	2.3	55.0	182.9
56	25	732.0	268.0	2.5	60.0	181.4
13	31	766.0	234.0	2.1	62.2	149.2
42	36	758.0	242.0	2.0	62.0	156.0
9	40	733.0	267.0	2.7	59.3	186.0
38	50	748.0	252.0	2.5	55.0	170.6
57	54	770.0	230.0	2.3	57.0	145.3
14	65	800.0	200.0	3.1	60.0	114.8
15	70	790.0	210.0	2.7	56.0	131.6
41	78	781.0	219.0	2.5	61.0	130.4

The venous blood of women gave, in 1000 parts:

2	22	780.0	220.0	2.5	60.0	133.4
47	33	773.0	227.0	2.9	59.0	140.0
48	48	786.0	214.0	3.1	60.0	126.0
35	50	795.0	205.0	2.1	58.4	110.3

The venous blood of virgins gave, in 1000 parts:

39	22	814.0	186.0	2.7	60.0	100.0
33	38	774.0	226.0	2.7	68.4	131.5
29	48	760.0	240.0	2.7	50.0	162.4

In my observations on Denis's method of analyzing blood I pointed out the reasons why some of the constituents would not be correctly determined. It is obvious that, in these analyses, two of my characteristics of healthy venous blood, namely, the proportions both of the solid constituents and of the blood-corpuscles are given in excess. I fix the proportion of the solid residue by an exact determination of the water, at about 20%, whereas these analyses would bring it up to 26.8%. Still greater discrepancies occur in the relative proportion of the albumen to the blood-corpuscles. In my analysis the proportion of the albumen to the haemato-globulin (the principal constituent of the blood corpuscles) is as 75: 100 or 1: 1.5. The proportion assigned by Lecanu is much the same, but approximates to the ratio 1: 2; whereas Denis's proportion is usually 1: 3 and often higher. Denis's amount of fibrin is larger than mine, but less than Lecanu's, for if the mean of the first 10 of his analyses be taken, the result is 24%.

In the estimation of the colouring matter there are, as might have been anticipated, considerable differences. The mean of my two analyses gives it as 6.2 in 1000 parts of blood; and in 100 parts of haemato-globulin the average is 5.7.

This quantity of colouring matter, when estimated, according to

my method, from an analysis of 8-12 grains of dried blood, contains, moreover, haemaphæin and some fat; in consequence of the very small portion in which the two latter occur, (the former being frequently not more than from .14 to .3, and the latter about .3 of a grain,) I seldom attempted their separation unless I had reason to believe that a considerable quantity of haemaphæin was present. The quantity of haematin, in my two analyses, is therefore placed rather too high. Lecanu estimates the haematin in 1000 parts of blood at 2.27, which is considerably less than half my average. This difference is owing partly to the circumstance of Lecanu's analyses being made with blood corpuscles not thoroughly deprived of their fibrin, and which possibly retained a portion of moisture, and partly to the fact that Lecanu, by working on larger quantities, was enabled to remove all the haemaphæin and fat. The average quantity of peroxide of iron in Denis's experiments amounted to .09%, which would correspond (according to my own and Lecanu's analyses,) with about 0.9 of haematin.

From the 10 analyses of man's blood, the mean quantity of blood-corpuscles is 15.8%. Hence Denis perfectly agrees with me in the consideration that the blood-corpuscles contain 5.7% of haematin.

I have not attempted any separation of the salts: Denis has, however, in all his analyses, determined the carbonates, phosphates, and chlorides.

It results from his important and elaborate observations, that although the relative proportions of the salts vary considerably, the limits to which they are restricted are not very extended. I shall now give the quantity of the salts in the 10 analyses of man's blood, preserving the same order of succession as before.

1000 parts of healthy venous blood in a man contained:

No. in Denis's work.	Age.	Carbonate of soda.	Chloride of sodium.	Chloride of potassium.	Carbonate of lime.	Phosphate of lime, with traces phosphate of magnesia.
46	23	2.0	4.9	3.9	2.8	0.6
56	25	2.0	4.2	3.6	2.6	0.6
13	31	1.2	4.0	2.1	1.2	0.7
42	36	1.0	4.0	3.1	2.0	0.3
9	40	2.1	5.2	2.3	1.8	0.4
38	50	1.3	4.9	2.5	1.3	0.5
57	54	2.0	4.2	3.5	2.7	0.5
14	65	2.1	5.0	1.0	1.3	0.2
15	70	1.0	4.0	2.1	1.3	0.5
41	78	1.5	4.2	3.2	1.7	0.5

The mean deduced from these 10 analyses is—

47 1.6 4.4 2.7 1.8 0.5

And the average proportion of the salts, collectively, would be 11.1 in 1000 parts of blood.

[Nasse has analyzed human blood, and found in 100 parts:

Water	-	-	-	-	798.402
Solid constituents	-	-	-	-	201.598
Fibrin	-	-	-	-	2.233

Fat	-	-	-	-	-	1.970
Albumen	-	-	-	-	-	74.194
Blood-corpuscles	-	-	-	-	-	116.529
Soluble salts	-	-	-	-	-	6.672

The soluble salts consisted of—

Alkaline phosphates	-	-	-	-	-	0.893
Alkaline sulphates	-	-	-	-	-	0.202
Alkaline carbonates	-	-	-	-	-	0.957
Chloride of sodium	-	-	-	-	-	4.690
						6.672

The insoluble salts were also estimated as follows:

Peroxide of iron	-	-	-	-	-	0.634
Lime	-	-	-	-	-	0.183
Phosphoric acid	-	-	-	-	-	0.201
Sulphuric acid	-	-	-	-	-	0.052
						6.672

The insoluble salts and extractive matters are probably included, in Nasse's analysis, in the albumen.

Becquerel and Rodier have recently published an elaborate memoir on the composition of the blood in health and disease. Their method of analysis is founded on nearly the same principles as that of Andriu and Gavarret, which will be found at the commencement of our section on Diseased Blood.

The following table is drawn up from the analyses of the blood of 11 men, varying in age from 21 to 56 years, all of whom were considered by the experimenters to be in perfect health.

	Mean.	Max.	Min.
Density of defibrinated blood	1060.2	1062.0	1059.0
Density of serum	1028.0	1030.0	1027.0
Water	799.0	800.0	760.0
Solid constituents	201.0	240.0	200.0
Fibrin	2.2	3.5	1.5
Fat ¹	3.2	6.6	2.0
Albumen	69.4	73.0	62.0
Blood-globules	141.1	152.0	131.0
Extractive matters and salts	6.8	8.0	5.0

1000 parts of incinerated blood contained:

	Mean.	Max.	Min.
Chloride of sodium	3.10	4.20	2.30
Other soluble salts	2.50	3.20	2.00
Earthy phosphates	0.33	0.70	0.22
Iron	0.56	0.63	0.51

The composition of the blood in the healthy female, as deduced from eight analyses, is given in the following table:

	Mean.	Max.	Min.
Density of defibrinated blood	1057.5	1060.0	1054.0
Density of serum	1027.4	1030.0	1026.0
Water	791.1	813.0	773.0

¹ This fat contained:

Serolin	-	-	0.020	0.080	inappreciable.
Phosphorized fat	-	-	0.488	1.000	0.270
Cholesterin	-	-	0.088	0.175	0.030
Saponified fat	-	-	1.004	2.000	0.700

Solid constituents		Mean.	Max.	Min.
Fibrin	- - -	2-2	26	1-6
Fat ¹	- - -	2-2	57	20
Albumen	- - -	70-5	75-5	65-0
Blood-globules	- - -	137-2	137-5	113-0
Extractive matters and salts	- - -	7-4	8-5	6-2

1000 parts of the incinerated blood contained:

	Mean.	Max.	Min.
Chloride of sodium	- - -	3-90	4-00
Other soluble salts	- - -	2-90	3-00
Earthy phosphates	- - -	0-35	0-65
Iron	- - -	0-64	0-67

The salts have been analyzed by Marchand. They amount (he observes) to 6-28—6-82% of the dried residue. The four following analyses are given in his 'Lehrbuch der Physiologischen Chemie':

	1.	2.	3.	4.
Chloride of sodium	- - -	3-91	3-42	3-61
Chloride of potassium	- - -	0-32	0-21	0-31
Carbonate of soda	- - -	0-62	0-52	0-79
Sulphate of Soda	- - -	0-31	0-52	0-38
Phosphate of soda	- - -	0-56	0-78	0-68
Phosphate of lime	- - -	0-26	0-31	0-28
Phosphate of magnesia	- - -	0-21	0-20	0-25
Lactate of soda	- - -	0-38	0-28	0-35
Lactate of ammonia	- - -	0-12	0-10	0-00
	—	—	—	—
	6-68	6-28	6-78	6-68

In 100 parts of the ash of human blood there are contained, according to Enderlin:

Tribasic phosphate of soda (3 Na, PO ₄)	22-100	
Chloride of sodium	- - -	54-769
Chloride of potassium	- - -	4-416
Sulphate of soda	- - -	2-461
Phosphate of lime	- - -	3-636
Phosphate of magnesia	- - -	0-769
Peroxide of iron and phosphate of iron	- - -	10-770
		= 83-740 soluble salts.
		= 15-175 insoluble salts.

On the differences of the blood, dependent on sex.

Lecanu² concludes from his analyses that the venous blood of males is richer in solid constituents than that of females, but that the quantity of albumen in both is the same. The following are the maxima, minima, and mean results of his analyses:

	Water in venous blood		Albumen in ditto.	Albumen in ditto.
	of men.	Ditto in that		
	Maximum	of females.		
Minimum	- - -	805-263	78-270	74-740
Mean	- - -	778-625	57-690	59-159
		791-944	68-080	66-949

¹ This fat contained:

	Mean.	Max.	Min.
Serolin	- - -	0-020	0-060
Phosphorised fat	- - -	0-464	0-600
Cholesterin	- - -	0-090	0-200
Saponified fat	- - -	1-046	1-800

² Etudes Chimiques, etc., p. 65; or Journal de Pharmacie, vol. 18, p. 551.

Having only made two analyses of the blood of healthy persons, I am not in a position to draw any inferences regarding differences in its composition, dependent upon sex. I have, however, deduced, from Denis's analyses, a table indicating the differences that exist between male and female blood, at the same age.

<i>Blood of Males:</i>	Water.	Blood-corpuscles.	Albumen.	Fibrin.
Maximum . . .	790·0	157·1	63·0	9·9
Minimum . . .	733·3	102·0	52·3	2·1
Mean . . .	758·0	147·9	57·5	2·5
<i>Blood of females:</i>				
Maximum . . .	820·0	162·4	66·4	3·0
Minimum . . .	750·0	88·1	50·0	0·25
Mean . . .	773·0	138·0	61·2	0·27

Hence it appears that the analyses of Denis¹ bear out Lecanu's statement with regard to the smaller proportion of water in male than in female blood; the albumen, however, appears to be rather more abundant in female than in male blood. The proportion of blood-corpuscles is smaller, and of fibrin rather larger than in the blood of the male.

[From the analyses of Becquerel and Rodier, it appears that the influence of sex is so great, that, in order to arrive at any correct conclusions respecting the deviation of morbid blood from the healthy standard, diseased male and female blood must be always contrasted with the respective male and female blood in a state of health. The mean differences may be seen by a glance at the following table:

	Male.	Female.
Density of defibrinated blood . . .	1060·0	1057·5
Density of serum . . .	1028·0	1027·4
Water . . .	779·0	791·1
Fibrin . . .	2·2	2·2
Sum of fatty matters . . .	1·60	1·62
Serolin . . .	0·02	0·02
Phosphorized fat . . .	0·488	0·464
Cholesterin . . .	0·088	0·090
Saponified fat . . .	1·004	1·046
Albumen . . .	69·4	70·5
Blood-corpuscles . . .	141·1	127·2
Extractive matters and salts . . .	68	74
Chloride of sodium . . .	3·1	3·9
Other soluble salts . . .	2·5	2·9
Earthy phosphates . . .	0·334	0·354
Iron . . .	0·566	0·541

Hence female blood differs materially from the blood of the male in the amount of water and of blood-corpuscles.]

On the differences of the blood, dependent on constitution.

Denis concludes from his analyses that, generally speaking, the stronger the constitution is, the greater will be the amount of solid constituents, and especially of blood-corpuscles. If age is also taken into consideration, my observations confirm those of Denis. At

¹ Op. cit. p. 290.

equal ages, the blood in weak constitutions is less abundant in solid constituents and hæmato-globulin than in stronger constitutions.

On the differences in the blood, dependent upon temperament.

According to Lecanu,¹ temperament has an influence upon the composition of the blood. He infers from his analyses that the blood of lymphatic persons is poorer in solid constituents, and especially in blood-corpuscles, than that of persons of sanguineous temperament, while the quantity of albumen is much the same in both. The following table will illustrate these views.

1000 parts of blood contained on an average:

		Men of sanguineous temperament.	Men of lymphatic temperament.
Water	- -	786-584	800-566
Albumen	- -	65-850	71-781
Blood-corpuscles	- -	136-497	116-667
		Women of sanguineous temperament.	Women of lymphatic temperament.
Water	- -	793-007	803-710
Albumen	- -	71-264	68-660
Blood-corpuscles	- -	126-174	117-300

On the differences in the blood, dependent on age.

My own observations, which, however, chiefly refer to diseased blood, lead to the conclusion that the blood of young persons contains a larger proportion of solid constituents, and especially of blood-corpuscles, than that of older persons. Lecanu and Denis have, however, made this a point of especial inquiry, and have extended their analyses over a wide range of ages.

I have drawn up the following table from the numerous analyses of Denis, the blood being considered healthy.

1000 parts of healthy blood of males contained:

Age. 14 years.	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Albumen.
23	733-0	267-0	2-3	182-9	55-0
25	732-0	268-0	2-5	181-4	60-0
31	766-0	234-0	2-1	150-1	62-2
33	783-0	217-0	2-9	129-3	60-0
40	750-0	250-0	2-5	167-8	55-1
46	769-0	231-0	2-5	156-9	48-5
50	748-0	252-0	2-5	170-9	55-0
53	790-0	210-0	2-6	100-0	63-0
54	798-0	202-0	3-0	111-0	63-0
65	800-0	200-0	3-1	114-8	60-0
70	790-0	210-0	2-7	132-3	56-0
80	781-0	219-0	2-5	130-4	61-0

1000 parts of healthy blood of females contained:

4	833-0	167-0	2-8	80-5	64-0
6	820-0	180-0	2-5	97-6	59-0
12	787-0	213-0	2-3	130-0	57-0
15	774-0	226-0	2-5	135-7	65-0

¹ Op. cit. p. 66.

Age. 20 years.	Water.	Solid residue.	Fibrin.	Blood-corpuses.	Albumen.
22	772-0	228-0	2-5	144-2	57-0
32	780-0	230-0	2-5	133-4	60-0
38	750-0	250-0	3-0	173-4	51-0
48	774-0	226-0	2-7	131-5	68-4
52	786-0	214-0	3-1	126-0	60-0
74	820-0	180-0	2-9	88-1	68-0
	745-0	255-0	9-5	171-1	55-0

It appears from these tables, especially from the second, that the blood is less abundant in solid constituents, and particularly in blood-corpuses in early life, than at the period of maturity. From the latter period (or rather sooner) to middle life the proportions of the corpuscles and of the solid constituents continues large; from that time to an advanced age they are subject to a decrease. [Becquerel and Rodier observe that, after the age of 40 or 50, there is a decided and progressive increase of cholesterin in the blood.]

Denis has made a comparative analysis of the blood of the mother and of the foetus; he found that the latter was richer in solid constituents and in blood-corpuses than the former.

The two following analyses, one of the venous blood of the mother, the other of the placental blood as it issued from the artery of the cord, may serve as an additional illustration of the point.

The blood of the umbilical artery was of a brown-red colour, smelled of the liquor amnii, and became of a brighter colour on being exposed to the air.

	Venous blood of mother.	Blood of umbilical artery.
Water	781-0	701-5
Solid residue	219-0	298-5
Fibrin	2-4	2-2
Albumen	50-0	50-0
Blood-corpuses	139-9	222-0
Peroxide of iron	0-8	2-0
Phosphorized fat	9-2	7-5
Ozmazome and cruxin	4-2	2-7
Salts	12-5	12-1

The difference in the solid constituents and in the blood-corpuses is obviously very considerable; the same is the case with the iron, the ratio being 1 to 2-5.

The mass of the blood in the foetus increases in a very rapid ratio with the development. The proportion of corpuscles is more augmented, and the quantity of water is less than occurs at any subsequent period of life. Even for some time after birth the mass of the blood is relatively large, and the proportion of blood-corpuses and of iron contained in them is considerably above the ordinary standard.

Denis has made some experiments on the difference between the blood of very young animals and those of mature age, which confirm the observations already made. His experiments were instituted on dogs.

	Blood of a dog, 3 months old.	Blood of a puppy, 1 day old.
Water	830.0	790.0
Solid residue	170.0	220.0
Fibrin	24	20
Albumen	58.6	46.0
Blood-corpuscles	97.0	165.0
Extractive matter and salts	12.0	7.0

When the skin of the new-born animal loses its red tint, the blood becomes more watery, the blood-corpuscles and the quantity of iron are diminished, and it becomes relatively, but not absolutely, poorer, for its quantity at the same time increases. Subsequently, however, when the generative powers begin to be developed, the corpuscles and the iron increase, and the relative proportion of water diminishes. At the period of full development the excess of corpuscles and iron serve in maintaining the necessary energy of that part of the system, and till the generative powers begin to flag the blood remains abundant in solid constituents, and more especially in corpuscles.

These observations are suggested by the results obtained by Denis,¹ as will be clearly seen by the following table, which was drawn up by that chemist himself.

The mean amount of solid constituents and of blood-corpuscles at different ages are given in the following proportions:

	Solid constituents.		Blood-corpuscles.
In 5 individuals between 5 months and 10 yrs.	170		11
13 " 10 years and 20 yrs.	200		14
11 " 20	30	240	17
12 " 30	40	240	17
6 " 40	50	240	17
8 " 50	60	220	15
2 " 60	70	210	14

The following table shows that Lecanu's analyses confirm those of Denis and myself.

Age.	Water.	Solid residue.	Blood-corpuscles.	Albumen.
25	778.625	221.375	146.885	62.949
30	788.323	211.677	131.688	71.061
34	795.670	204.130	115.650	78.120
38	783.890	216.110	148.450	67.890
45	780.210	219.790	132.820	72.970
48	805.263	194.737	117.484	65.123
62	801.871	198.129	121.640	65.389

ON DISEASED BLOOD.

The pathological chemistry of the blood.

The question whether there exists such a thing as *diseased blood* is easily answered. The material deviations from its normal condition exhibited by the blood in its physico-chemical relations, in certain morbid conditions of the system, have long been recognised by pathologists.

The quantity of the fibrin is sometimes found to be very much increased, while in other cases it is present only in such very small

¹ *Recherches*, pp. 289, 290.

proportions that no clot is formed. The blood will sometimes be found to be very rich in solid constituents, and especially in blood-corpuscles; while at other times it will be so poor as to resemble coloured water. In some instances the corpuscles will sink rapidly in whipped blood; while in others they will only deposit themselves slowly and imperfectly, so that merely a thin layer of serum remains above them. It will also sometimes contain substances which are not found in it in a normal state, as colouring matter of the bile, sugar, or urea. All these are deviations from the normal state of the blood; and if we term that blood healthy, which is constituted in the ordinary manner, and properly discharges its various functions, we are perfectly justified in considering blood as diseased which does not fulfil these conditions.

The analyses published by Andral and Gavarret,¹ in their elaborate essay upon this subject, correspond in their results, generally speaking, with those instituted by myself. They, however, usually assign a higher proportion to the corpuscles (especially in the blood during inflammatory diseases) than I have found to occur. It is hardly probable that such differences should arise from the geographical positions of the observers, although, generally speaking, the blood may be richer in solid constituents and in corpuscles, in southern than in northern regions: it is more likely that they are caused by the different methods of analyses pursued by the French observers and myself. I have tried both methods, and consider it useful, if not necessary, to state the results of my trial.

In the analyses of Andral and Gavarret, the blood is received into two six-ounce vessels. The first and fourth quarters are received in one vessel, the second and third in the other. In one, the blood is allowed to coagulate spontaneously; in the other, it is whipped, in order to obtain the fibrin, which must be carefully washed. When the coagulation is effected, the clot must be carefully removed from the serum, and we must dry (*a*) the fibrin which has been obtained by whipping one portion of the blood; (*b*) the serum; and (*c*) the clot. By weighing the dried fibrin we know the quantity of that constituent contained in the clot. By weighing the dried serum we know the proportions of water and of solid constituents contained in it. Lastly, we weigh the dried clot: the quantity of water which it gives off is estimated as serum, and the solid residue due to it is readily calculated. By deducting from the weight of the dried clot the weights of the fibrin and of the solid residue of the serum contained in the clot, we obtain the amount of the globules. Hence we have (1) the weight of the fibrin; (2) the weight of the globules; (3) the weight of the solid residue of the serum; and (4) the weight of the water.

This method is simple, and easy of application, in cases in which it is unnecessary to ascertain the proportions of hæmatin, globulin,

¹ *Annales de Chimie et de Physique*, vol. 75, p. 225.

fat, haemaphæin, extractive matters, and salts, separately. I shall, however, show that an error may easily arise in the determination of the blood-corpuscles, if the drying has not been perfectly effected.

In order to ascertain what would be the amount of differences, I analyzed the same blood by their method, and by my own. About eight ounces of blood were received in a glass, from the arm of a woman, aged 35 years. It was rapidly stirred; about a fourth part of it was poured into a small glass, and the fibrin removed in the ordinary manner, by whipping. The larger portion was left to coagulate.

I. Analysis of the defibrinated blood.

The blood, including the fibrin, weighed 950 grains, of which the fibrin, when washed and thoroughly dried, weighed 1.9 gr. Hence 1000 parts of blood contain 2.0 of fibrin.

112.42 grains of defibrinated blood left, after the thorough removal of the water, a solid residue, amounting to 20.33 grs.

Hence 1000 parts of blood contained 180 of solid constituents; 7.7 grains of the dried residue were boiled in spirit of .925, to which three drops of dilute sulphuric acid were subsequently added, as long as the spirit continued to take up any thing more, and until a bright gray-green residue was left. This residue, which is composed of the albumen of the blood, when dried, weighed 3.31 grains.

The red alcoholic solution was saturated with ammonia, and evaporated to a small residue. The haemato-globulin, which separated perfectly in this way, was then washed several times with water, dried, and weighed. Its weight amounted to 4 grains. The extractive matters and salts (including loss) may therefore be estimated at .39 of a grain.

Now since 1000 parts of the defibrinated blood contain 180 of solid residue, the blood must contain:

Water	-	:	:	:	:	818.00
Solid residue	-	:	:	:	:	182.00
Fibrin	-	:	:	:	:	2.00
Albumen	-	:	:	:	:	77.40
Haemato-globulin	-	:	:	:	:	93.60
Extractive matters, salts, and loss	-	:	:	:	:	9.00
						1000.00

II. Analysis of coagulated blood, according to the method of Andral and Gavarret.

a. The serum weighed 1406 grains.

b. The clot weighed 1228 grains.

In order to ensure a greater degree of accuracy in my results, I evaporated only a portion of this quantity.

375.14 grains of the clot, when dried, cautiously pulverized, and again heated, left 112.54 grains. Hence 100 parts of the clot con-

tained 30.0 of solid constituents. 449.98 grains of serum left 42.66 of solid residue, which corresponds therefore with 9.5%.

1000 parts of blood consist of 533.8 of serum and 466.2 of clot, of which the serum gives a residue of 50.7, and the clot of 139.86 parts. The solid residue of 1000 parts amounts therefore to 190.56.

From the residue of the clot we deduct 2.0 for fibrin, and 31.0 for the solid residue of the serum contained in it, which must be added to the 50.7. Consequently 1000 parts of blood contain,

Water	-	:	-	-	-	809.44
Solid residue	:	:	:	:	:	190.56
Fibrin	-	-	-	-	-	2.00
Solid residue of serum	:	:	:	:	:	79.70
Blood-corpuscles	-	-	-	-	-	108.86
						1000.00

The differences between these analyses are obvious. The solid constituents obtained by Andral and Gavarret's method are 8.5 higher, in 1000 parts of blood, than by mine; moreover, the quantity of corpuscles obtained by them considerably exceeds the haemoglobin separated by my method. If we assume that the 8.5 parts of water which Andral and Gavarret's method did not succeed in removing, were retained in the clot, the corpuscles would be reduced from 108.86 to 98.3: in which case the discrepancy between the two analyses would be much less striking.

1000 parts of blood would then contain:

	<i>According to Simon.</i>	<i>According to Andral and Gavarret.</i>
Fibrin	- 2.00	Fibrin - 2.00
Albumen, with extractive matters, and salts	86.40	Solid residue of serum - 30.50
Hæmato-globulin	93.60	Blood-corpuscles - 99.50

It must, however, be remarked, that the sum of the hæmatin and globulin, in my analyses, can never represent the absolute quantity of blood-corpuscles. As has been previously remarked, the nuclei and capsules of the blood-corpuscles have been estimated as albumen by my method, as fibrin by Berzelius, and as appertaining to the corpuscles by Andral and Gavarret.

Their absolute weight has never been accurately ascertained,¹ but it cannot be larger, since the quantities of fibrin obtained by washing the clot, and by whipping fresh blood differ very little. Further, a portion of fat separated by my method, belongs to the blood-corpuscles, and we cannot deny the possibility of the corpuscles containing albumen.

My analyses, moreover, aim not merely at the determination of the proportion of the fibrin, of the corpuscles, and of the solid residue of the serum, but they are intended to embrace the determination of the most important proximate constituents of the blood; and if the

¹ Nasse (*Das Blut in mehrfacher Beziehung, &c.*, Bonn, 1836, p. 109) has attempted to form a quantitative analysis of the nuclei.

haemato-globulin, or possibly the globulin be regarded as constituting the principal mass of the corpuscles, I can succeed in tracing their increase or decrease by means of the proportion of the haemato-globulin or globulin.

The following objections may likewise be brought against Andral and Gavarret's method.

In cases where no consistent clot is formed, but where there is merely a slight gelatinous coagulation, as frequently occurs in blood deficient in fibrin, the serum and the clot cannot be separated with any degree of exactness. If the clot be allowed to stand for some hours in order to induce a more perfect separation of the serum, the water partially evaporates, and the ratio of the solid constituents of the clot to the water becomes changed, and consequently too high a number is assigned to the corpuscles. The difficulty of thoroughly removing the water varies in a direct proportion with the quantity of the blood submitted to evaporation. Serum, comparatively poor in solid constituents, gives only a slight residue, from which the water can be more readily expelled, than from the more abundant residue left by the clot: in proportion to the water remaining in the clot, the quantity of corpuscles found by this method will be increased, as will be clearly seen by the following illustration.

1000 parts of blood are composed of 500 parts of serum and 500 of clot.

The serum leaves a solid residue of 50, or $10\frac{1}{2}$; the clot of 150, or $30\frac{1}{2}$.

The 350 parts of water in the clot are to be estimated as serum, and thus give a residue of 35 parts; so that 1000 parts of blood, (the fibrin not being taken into consideration) consist of:

Water	:	:	:	:	800
Solid residue	:	:	:	:	200
Blood-corpuscles	:	:	:	:	115
Residue of serum	:	:	:	:	85

If, however, the clot had not been perfectly dried, and if only 1 per cent. of water in relation to the weight of the whole blood had been retained, we should have obtained the following result:

500 parts of clot would then give 160 of solid residue, and there would therefore be 340 of water, which, estimated as serum, would yield 34 of residue; consequently the corpuscles would be estimated at 126, and 1000 parts of blood would consist of:

Water	:	:	:	:	790
Solid residue	:	:	:	:	210
Blood-corpuscles	:	:	:	:	126
Residue of serum	:	:	:	:	84

In all other methods of analyzing the blood in which the water is determined by a separate process, and the dried residue is used for further investigation, an error in its estimation will simply increase the absolute quantity of the solid constituents, without disturbing their relative proportions. But in the application of their method it

is easy to see that each per-centge of retained water not only increases the absolute quantity of the solid constituents in the amount of $1\frac{1}{2}$ %, but also the weight of the corpuscles, not only by the addition of the retained water, but also by the weight of the residue of the serum, due to an equal quantity of water, and which amounts to $1\frac{1}{2}\%$.

Moreover, the supposition of Andral and Gavarret, that the humidity of the clot should be considered as serum is totally devoid of foundation. The corpuscles cannot be supposed to swim in the plasma as dry molecules, and it has not been proved that the fluid, with which they are filled, is the fluid of the serum.

These observations are sufficient to show that Andral and Gavarret's method, and my own, give somewhat different results: the differences, however, are not very material, and are easily explicable on the grounds already stated.

The changes which the composition of the blood may experience in its various pathological conditions, are either dependent upon the quantity of solid residue generally, or upon the changed relative proportions that the various proximate constituents bear to each other.

If we assume the composition of healthy blood, (as deduced from the mean of my analyses) to be represented by

Water	-	-	-	-	-	795-278
Solid residue	-	-	-	-	-	204-022
Fibrin	-	-	-	-	-	2104
Fat	-	-	-	-	-	2346
Albumen	-	-	-	-	-	76-600
Globulin	-	-	-	-	-	103-022
Hæmatin	-	-	-	-	-	6-209
Extractive matters and salts	-	-	-	-	-	12-012

the following differences will be found to occur among the specimens of diseased blood which I have analyzed. The quantity of—

Water	-	-	may vary from	888-0	to	750-9
Solid residue	-	-	"	250-0	1190	
Fibrin	-	-	"	9-1	a trace	
Fat	-	-	"	4-3	0-7	
Albumen	-	-	"	131-0	55-1	
Globulin	-	-	"	106-6	30-8	
Hæmatin	-	-	"	8-7	1-4	
Hæmato-globulin	-	-	"	115-4	31-2	
Extractive matters and salts	-	-	"	16-5	7-6	

The analyses of the French chemists gave the following results, with regard to this subject.

Taking the mean of Lecanu's analyses of healthy blood as a standard, and contrasting with it the extreme results which were found by Andral and Gavarret in diseased blood, we have the following results:

Lecanu's analysis.

Water	-	-	-	-	-	790
Solid residue	-	-	-	-	-	210
Fibrin	-	-	-	-	-	3
Organic residue of serum	-	-	-	-	-	72
Inorganic ditto	-	-	-	-	-	8
Blood-corpuscles	-	-	-	-	-	127

Andral and Gavarret's Deviations.

Water	-	-	from	915-0	to	725-0
Solid residue	:	:	"	275-0		85-0
Fibrin	:	:	"	105		0-9
Solid residue of serum	:	:	"	114-0		57-0
Blood-corpuscles	:	:	"	185-0		21-0

From these data, it appears, that although the proportions of all the constituents are subject in disease to a certain amount of change, the variation is the most striking with regard to the fibrin and globulin.

The former is found in my analyses occasionally to exceed four times the average quantity, and in Andral and Gavarret's, three and a half times; while the latter may diminish, according to my analyses, to a mere trace; and according to Andral and Gavarret's, to one sixth of the normal quantity.

These determinations must not, however, be regarded as absolute: they are dependent on various causes, and can be explained in more ways than one.

For instance, the 21 parts of blood-corpuscles were observed by Andral and Gavarret in the blood which left a residue of only 85, while the 185 of corpuscles occurred in blood which gave a residue of 275. Hence the per-centages of the corpuscles in these two cases in regard to the solid residue, are 25 $\frac{1}{2}$ and 67 $\frac{1}{2}$ respectively.

The deviations in the proportions of the various constituents do not occur singly, for instance, we do not find the other constituents in normal proportions, and the blood-corpuscles alone very low; neither are they all found simultaneously deficient or in excess: but there exists, as we shall soon see, a certain antagonism between the proportions of the individual constituents. Thus we find that when the fibrin is much increased, the corpuscles are diminished in quantity, and vice versa.

In every 100 parts of the residue of healthy blood, we have 1 of fibrin and 53 of hæmato-globulin. In diseased blood I have observed the following proportions:

Fibrin.	Hæmato-globulin.
1-4	43
1-6	40
1-7	40
2-0	42
2-0	39
2-1	36
3-0	28
6-0	22

A similar relationship is exhibited in the analyses of Andral and Gavarret; the range of the corpuscles is, however, not so extensive.

	Fibrin.	Blood corpuscles.
Healthy blood	- - -	16 61
Diseased blood	- - -	25 60
"	- - -	32 57
"	- - -	41 57
"	- - -	42 54
"	- - -	48 58
"	- - -	50 60

The connexion between the fibrin and blood-corpuscles is still more strikingly exhibited in some of the analyses of Andral and Gavarret, in which blood was taken several successive times from the same patient. We select four cases by way of illustration:

Venection.	Fibrin.	Blood-corpuscles.	Fibrin.	Blood-corpuscles.	Fibrin.	Blood-corpuscles.	Fibrin.	Blood-corpuscles.
1st	63	130	61	123	40	111	56	133
2d	77	106	72	120	55	107	55	131
3d	82	112	78	112	65	101	91	128
4th	93	103	102	101	90	83	94	102

In the following table drawn up from Andral and Gavarret's analyses, the first column gives the proportions of fibrin and of corpuscles in 100 parts of solid residue. The second column does the same, only that in this case the quantity of fibrin is considered constant, and is represented by 1·5, and the proportion of corpuscles is estimated accordingly: an arrangement which makes their increase more obvious.

	Fibrin.	Corpuscles.	Fibrin.	Corpuscles.
Healthy blood	-	-	1·5	61
Diseased blood	-	-	1·5	64
"	-	-	1·5	65
"	-	-	1·5	66
"	-	-	1·5	69
"	-	-	1·5	72
"	-	-	1·5	74
"	-	-	1·5	81
"	-	-	1·5	90
"	-	-	1·5	90
"	-	-	1·5	91
"	-	-	1·5	96
"	-	-	1·5	105
"	-	-	1·5	180

[Becquerel and Rodier have laid it down as a general law that "bleeding exerts a remarkable influence on the composition of the blood, the greater the oftener the bleeding is repeated." The three following tables show the mean results of the first, second, and third venesects, performed on a certain number of Cruveilhier's patients. Ten patients were bled twice, and ten thrice, so that we have 20 first, 20 second, and 10 third bleedings.

Mean composition of the blood of twenty persons bled twice.

	1st Venection.	2d Venection.
Density of defibrinated blood	-	1055·0
Density of serum	-	1026·1
Water	-	7962
Solid residue	-	2038
Fibrin	-	37
Albumen	-	66·2
Blood-corpuscles	-	125·4
Extractive matters and salts	-	6·8
Fat	-	1·657
Consisting of—		
Serolein	-	0·027
Phosphorized fat	-	0·490
Cholesterin	-	0·173
Saponified fat	-	0·962
		0·047
		0·465
		0·150
		0·900

The salts in 1000 parts of blood were:

Chloride of sodium	-	-	-	-	28	34
Other soluble salts	-	-	-	-	27	25
Phosphates	-	-	-	-	0.435	0.417
Iron	-	-	-	-	0.527	0.488

Mean composition of the blood of ten persons bled three times.

	1st Venesection.	2d Venesection.	3d Venesection.
Density of defibrinated blood	-	1056.0	1053.0
Density of serum	-	1026.8	1025.3
Water	-	739.0	833.1
Solid residue	-	207.0	192.3
Fibrin	-	36	38
Albumen	-	65.0	63.7
Blood-corpuscles	-	129.3	116.3
Extractive matters and salts	-	7.7	6.9
Fat	-	1.062	1.584
Consisting of—Serolin	-	0.026	0.088
Phosphorized fat	0.037	0.489	0.450
Cholesterin	0.106	0.156	0.149
Saponified fat	0.893	0.851	0.919

The salts contained in 1000 parts of blood were:

Chloride of sodium	-	-	-	26	36	30
Other soluble salts	-	-	-	26	25	27
Phosphates	-	-	-	0.404	0.493	0.348
Iron	-	-	-	0.513	0.471	0.468

From these tables they draw the following conclusions. "In proportion to the number of venesectio[n]s the blood becomes impoverished and more watery; hence the fall in the density of the defibrinated blood. The albumen diminishes, but only slightly; hence the density of the serum is not much affected. The fibrin is quite uninfluenced by venesection, and its amount is determined by the nature and intensity of the disease. The extractive matters and salts are unaltered. There is a slight diminution in the amount of fat. The various salts are unaffected, and the iron, in consequence of its relationship to the corpuscles, is diminished. In short, the effect of venesection is to cause a great diminution of the corpuscles, while it only slightly lessens the amount of albumen."]

THE FIRST FORM OF DISEASED BLOOD, HYPERINOSIS.¹

Chemical characters of the blood.

The blood contains more fibrin than in the normal state, and the corpuscles decrease in proportion to the excess of fibrin; the fat is also increased. In proportion to the increase of the fibrin and fat, and the decrease of the corpuscles, the whole solid residue will be diminished.²

¹ Derived from ὑπερ and ινος, the fibre of flesh.

² Nasse (Das blut in mehrfacher Beziehung, &c.,) has arrived at similar conclusions; for he observes that the corpuscles and the fibrin are generally in an inverse ratio, and that blood exhibiting a decided genuine buffy coat is usually of low specific gravity, that is to say, the amount of water is increased.

Physical characters of the blood.

The blood coagulates more slowly than in the normal state; the clot is usually not small, but very firm and consistent, and does not break up for a considerable time. It is almost invariably covered with a true buffy coat, (which is produced by the sinking of the corpuscles before the occurrence of coagulation, and by the subsequent coagulation of the fibrin in the layer of serum.)¹ This buffy coat is firm, tough, and intimately connected with the clot; its edge is often turned upwards, and its surface uneven.² If the clot is small, the buffy coat and the surface of the clot are more or less cupped; the serum is of a pure lemon colour, not tinged red. When subjected to whipping, the fibrin separates in thicker and more solid masses than in ordinary blood. After the removal of the fibrin the corpuscles quickly sink, and frequently occupy only one fourth of the whole fluid, while, in healthy blood, they sink very imperfectly or not at all. The blood has always an alkaline reaction, and is of a higher temperature than in the ordinary state.

Lauer³ found the temperature of the blood in pneumonia as high as 100°, and in bronchitis it reached 101°.6. These temperatures are, however, not higher than are met with in healthy blood.

According to Becquerel the temperature may rise to 5°.4 in inflammatory disease and fevers.

According to Coupil it amounts, in inflammatory disorders, to 106°—111°.7, and at the inflamed region to 112°.4.

The microscope has not yet succeeded in detecting any constant peculiarities.

The blood occurs in a state of hyperinosis in all inflammatory disorders (Phlogoses.)

In proportion to the firmness of the clot, the concavity of its surface, (the cupping,) and the toughness, and thickness of the buffy coat, is the degree of inflammation; and, conversely, the thinner and more friable the clot is, the less intense is the disorder. We also find, accompanying these physical symptoms, an excess of fibrin, and a diminution of hæmato-globulin, as well as of the solid constituents of the blood generally, and in proportion to the degree in which these phenomena are observed, we may infer a greater or lesser amount of inflammatory action.

[Before proceeding to the consideration of individual diseases, we may observe that Becquerel and Rodier have deduced the following law from their numerous analyses of morbid blood. "The develop-

¹ [The buffy coat does not consist of true fibrin, but of the binoxide and tritoxide of protein. (See page 19.)]

² The buffy coat is not exclusively connected with an inflammatory state of the blood; it occurs in other diseases, as, for instance, in chlorosis, but its properties are then very different. A very elaborate disquisition on the formation, and the proximate and remote causes of the buffy coat, occurs in Nasse's work, pp. 36—57, and 204—240.

³ Quedam de sanguinis different. in Mort. p. 15.

ment of an inflammatory disorder produces remarkable modifications in the composition of the blood, of which the most striking is the increase of fibrin."¹

The following table, extracted from their memoir, gives the mean results obtained from the analyses of blood in a number of cases of well marked inflammation.

		Males.	Females.
Density of defibrinated blood	- - - -	1056.3	1054.5
Density of serum	- - - -	1027.0	1026.8
Water	- - - -	791.5	801.0
Solid constituents	- - - -	208.5	199.0
Fibrin	- - - -	5.8	5.7
Albumen	- - - -	66.0	65.8
Blood-corpuscles	- - - -	128.0	118.6
Extractive matters and salts	- - - -	7.0	7.2
Fat	- - - -	1.742	1.669
Consisting of—Serolin	- - - -	0.020	0.024
Phosphorized fat	- - - -	0.602	0.601
Cholesterin	- - - -	0.136	0.130
Saponified fat	- - - -	0.984	0.914

The salts in 1000 parts of blood were:

Chloride of sodium	- - - -	3.1	3.0
Other soluble salts	- - - -	2.4	2.7
Phosphates	- - - -	0.448	0.344
Iron	- - - -	0.490	0.480

By a comparison of these results with the formulæ for healthy blood, (vide supra, p. 193,) we see that only three constituents, fibrin, cholesterin, and albumen, deviate from the normal standard. The first two of these constituents are increased, the last is diminished.]

I. PHLOGOSES OF THE CIRCULATING SYSTEM.

a. *Metrophlebitis puerperalis.*

In most of the cases of metrophlebitis puerperalis that have occurred in our lying-in institution as well as in the hospital, the blood exhibited all the symptoms of hyperinosis. According to Ebert's observations the clot was rather large, and so consistent that sections of it still displayed a powerful and well-marked tenacity. The surface, which was more or less concave, was either covered with a thin true buffy coat, or more frequently, with a rather thick, and often discoloured stratum of gelatinous substance, forming, what is termed, a false buffy coat. Gelatinous coagula, of a similar nature, were also frequently seen floating in the serum.

The microscope often detects pus in the blood, during the course of this disease. If, however, the quantity of pus is only small, its detection may be attended with much difficulty.² As the presence of pus in the blood has also been recognised in other pathological

¹ The authors merely regard this as a confirmation of the law established by Andral and Gavarret, not as an original discovery.

² According to Gendrin, when there is pus in the blood, the serum deposits a viscid urinary-like sediment, or else is turbid and cloudy.

conditions, and many observations have recently been made upon the subject, I shall refer to this point more particularly when I speak of the presence of foreign substances in the blood.

I have analyzed the blood of two women suffering from metrophlebitis puerperalis. The analyses gave:

	Analysis 15.	Analysis 16.
Water	836.360	785.560
Solid residue	163.640	214.440
Fibrin	7.640	4.440
Fat	3.120	4.320
Albumen	103.358	112.770
Globulin	40.000	74.130
Hæmatin	2.080	3.440
Extractive matters and salts	7.649	12.390
100 parts of hæmato-globulin contained 5·0 of colouring matter.		100 parts of hæmato-globulin contained 4·6 of colouring matter.

The blood in analysis 15 was taken from a woman aged 20 years, who was attacked in our lying-in institution with violent phlebitis uterina the day after her delivery. The pulse was full and hard, and 140 in the minute, previous to the bleeding. The post-mortem examination revealed a high degree of inflammation of the veins and of the uterus itself, with a copious deposition of pus.

In analysis 16, the blood was taken from a woman aged 20, who was seized fourteen days previously to the bleeding with a violent attack of phlebitis uterina, from which, however, she recovered by the use of venesection and mercury. Violent fever afterwards came on, accompanied by pain in the region of the uterus. The pulse was somewhat full and hard, and 132 in the minute. She died soon after, and the post-mortem examination proved the accuracy of the diagnosis.

[In a case of phlegmasia alba dolens, accompanied with fever, occurring in a woman aged 21 years, six weeks after delivery, Becquerel and Rodier found a considerable diminution of the blood-corpuscles (92·6,) and an augmentation of the fibrin (4·2.) The cholesterol was in excess, (·223,) and the phosphates were abundant.]

β. Carditis.

Lecanu¹ analyzed the blood of three men and five women, who were suffering from angio-carditis and endocarditis. Unfortunately he has made no observations on the physical characters of the blood, and the quantity of fibrin was also not ascertained. The analysis seems to have consisted simply in the separation of the clot from the serum, and then ascertaining the solid residue of each.

The blood of men gave the following results:

	Water.	Solid residue.	Residue of serum.	Blood-corpuscles.
1	821.02	178.98	77.59	101.30
2	880.48	119.52	77.62	41.90
3	807.27	192.73	96.35	96.33

¹ *Etudes Chimiques, etc., p. 110.*

The blood of women gave:

	Water.	Solid residue.	Residue of serum.	Blood-corpuscles.
4	873-45	126-55	86-10	40-45
5	868-62	131-38	79-89	51-49
6	866-61	133-39	89-69	43-70
7	877-51	122-49	77-00	45-49
8	845-14	154-86	85-80	69-06
Healthy blood	790-00	210-00	80-00	130-00

It is much to be regretted that the fibrin was not determined in these researches, as the proportions of the solid residue, and especially of the corpuscles, indicate a high degree of hyperinosis.

Blood taken by repeated venesects from the same patient during carditis, differs in the following respect from blood similarly taken in cases of bronchitis, pneumonia, peritonitis, rheumatism, &c.; in these latter it becomes gradually poorer in solid constituents, and especially in corpuscles, while in the former, at least if we may judge from two analyses of Lecanu, the reverse takes place.

The man whose blood formed the object of the second analysis, on venesection being repeated 12 hours afterwards, yielded blood which left a solid residue of 139-1, and the woman from whom the blood in the eighth analysis was derived yielded, on a repetition of the venesection, blood which contained:

Water	-	-	-	841-62
Solid residue	:	:	:	158-38
Residue of serum	:	:	:	81-79
Blood-corpuscles	:	:	:	76-58

Lecanu noticed in the blood of one of these men a solid floating mass, (which, when dried, weighed about 100 grains.) It had a fleshy appearance, and on a section being made it exhibited a solid, loosely attached nucleus, of a brick-red colour, in the centre, which slowly dissolved in water. On the second occasion of this patient being bled, the clot presented even a more singular appearance. It was almost entirely formed of agglomerated clusters of small, round, white, grape-like masses, which were composed centrally of a bright red gelatinous substance.

[In a case of pericarditis with effusion, occurring in a woman aged 40 years, in which the blood was analyzed by Becquerel and Rodier, the following results were obtained:

	1st Venesection.	2d Venesection.	3d Venesection.
Density of defibrinated blood	- 1045-8	1042-4	1045-5
Density of serum	- - - 1023-0	1021-8	1024-3
Water	- - - - 831-0		847-0
Solid constituents	- - - - 169-0		153-0
Fibrin	- - - - 2-3	2-3	3-4
Fat	- - - - 1-094	1-094	
Albumen	- - - - 53-0	51-0	60-4
Blood-corpuscles	- - - - 105-0	92-0	78-0

In the first analysis the phosphates were in excess (0-684;) in other respects the salts occurred in their normal proportions.

At the period of the third venesection, the heart-symptoms were

much alleviated. The most remarkable feature in this blood is the extreme diminution of the albumen. There was no albumen in the urine.]

II. INFLAMMATION OF THE RESPIRATORY ORGANS.

a. Bronchitis.

The blood usually exhibits, at least when the symptoms are at all urgent, decided indications of hyperinosis. The buffy coat is scarcely ever absent, the serum is clear, and the clot firm and consistent. The fibrin and fat are always more or less increased, and the hæmato-globulin diminished.

		Analysis 17.	Analysis 18.
Water	-	797·500	757·831
Solid residue	-	202·500	242·269
Fibrin	-	4·320	
Fat	-	3·650	3·393
Albumen	-	96·890	109·080
Globulin	-	76·530	106·650
Hæmatin	-	3·200	8·762
Extractive matters and salts	-	11·560	14·500
100 parts of hæmato-globulin con-			
tained 4·0 of colouring matter.		100 parts of hæmato-globulin con-	
			tained 8·4 of colouring matter.

In analysis 17 we observe, in a decided degree, the character of inflammatory blood, as far as regards the large quantities of fibrin and fat. The quantity of hæmato-globulin, 79·73, is not so much diminished in proportion to the albumen in this case, as in those of phlebitis uterina.

The patient was a robust man, of about thirty years of age, who had only been suffering from the disease three days; pulse hard and very frequent. The blood of analysis 18 was taken from a child three years of age, by leeches, which is the reason why the fibrin was not determined.

Andral and Gavarret¹ have analyzed the blood in six cases of bronchitis, and in all the instances in which fever was present, they found that well-marked character of inflamed blood, an increased quantity of fibrin. The maximum was 9·3, the minimum 5·7, in 1000 parts of blood.

I shall now give the results of their analyses.

Venection.	Water.	Solid residue.	Fibrin.	Blood corpuscles.	Solid portion of serum.
1st Case	1 763·3	236·7	7·3	148·8	80·6
	2 793·6	206·4	9·3	110·2	86·9
2d Case	1 789·6	210·4	6·3	117·6	78·0
	2 769·5	230·5	5·9	139·6	76·7
3d Case	1 782·2	217·8	5·9	129·4	76·3
	2 821·8	178·2	5·8	114·3	58·1
4th Case	1 800·2	199·8	6·0	131·3	62·5
	2 808·1	191·9	7·1	125·5	59·3
5th Case	1 808·3	191·7	5·7	98·2	87·8
6th Case	1 808·3	191·7	5·7	127·0	80·0
Healthy blood, according to Lecanu -	790·0	210·0	3·0		

¹ Annal. de Chim. et de Phys., Vol. 75, p. 225.

The decreasing ratio of the corpuscles, and the increasing ratio of fibrin is less striking in this disease than in pneumonia and rheumatism. Andral and Gavarret give the following explanation of the first case, in which the high number 148·8 is assigned to the blood-corpuscles. This individual exhibited symptoms of typhoid fever at the period at which he was received into the hospital. In the second analyses the number is less by 38·6 than before. The symptoms of typhoid fever had now disappeared, and made way for those of bronchitis: the increase of fibrin from 7·3 to 9·3 sufficiently indicates the progress of inflammation.

In the fourth case the small quantity of solid constituents in the serum was coincident with a highly albuminous state of the urine; the patient, who was about 30 years of age, had for some time been in a weak and emaciated state. The urine in the fifth case, (a debilitated person 28 years of age, whose lower extremities were oedematous,) also contained albumen.

Andral and Gavarret have likewise analyzed the blood in chronic bronchitis. They state that, as the febrile symptoms disappear, and the disease assumes the chronic form, the blood ceases to exhibit a large excess of fibrin, and in fact does not differ in any respect from ordinary or healthy blood.

The same is the case if the chronic bronchitis is combined with pulmonary emphysema.

The average of five analyses made on the blood of four persons suffering in this way, scarcely differs from ordinary blood.

	Water.	Solid residue.	Fibrin.	Blood-cor-puscles.	Solid portion of serum.
Mean of five analyses -	792·7	207·3	3·0	121·0	83·0
Healthy blood (Lecanu)	790·0	210·0	3·0	127·0	80·0

In one of these cases a second venesection was ordered, in consequence of the severity of the dyspnoea. The blood exhibited a diminution of 11 in the corpuscles, of ·6 in the fibrin, and of 22 in the solid constituents.

[Scherer has published an analysis of the blood of a woman in the seventh month of pregnancy, who was suffering from bronchitis, and probably from tubercular phthisis. The serum had a specific gravity of 1022·69, and contained in 1000 parts:

Water	-	-	-	-	911·516
Solid residue	:	:	:	:	88·484

The solid residue consisted of:

Albumen	-	-	-	-	77·978
Extractive matters	:	:	:	:	0·977
Salts	-	-	-	-	9·529

The whole blood contained, in 1000 parts:

Water	-	-	-	-	825·696
Solid residue	:	:	:	:	174·302
Fibrin	-	-	-	-	4·568
Albumen	-	-	-	-	70·636

Blood-corpuscles	-	-	-	71.069
Extractive matters	-	-	-	20.178(1)
Soluble salts	-	-	-	6.399
Earthy phosphates	-	-	-	1.825

The serum presented a singular milky appearance, arising from the presence of numerous minute granules in suspension. No fat-vesicles could be recognised by the microscope.

Becquerel and Rodier have analyzed the blood in eight cases of acute bronchitis, four males and four females. The mean results are expressed in the following table:

		Males.	Females.
Density of defibrinated blood	-	1056.7	1056.6
Density of serum	-	1027.1	1027.7
Water	-	793.7	803.4
Solid constituents	-	206.3	196.6
Fibrin	-	4.8	3.5
Fat	-	1.621	1.715
Albumen	-	64.9	68.8
Blood-corpuscles	-	129.2	115.3
Extractive matters and salts	-	5.8	7.3

The salts consisted of:

Chloride of sodium	-	-	-	32	33
Other soluble salts	-	-	-	29	28
Phosphates	-	-	-	0.346	0.309
Iron	-	-	-	0.513	0.479

β. Pneumonia.

The blood usually exhibits the characters of hyperinosis, more decidedly in pneumonia than in most other inflammatory diseases, it also retains its heat for a longer period.¹ The clot is rather below the ordinary size, very consistent, and does not break down for a considerable time. It admits of being sliced, and the sections retain their consistency for some time. Its surface is covered with the buffy coat, and is more or less cupped. The serum is of a pure yellow colour. The quantity of solid constituents is usually less than in healthy blood.

The maximum of fibrin in my analyses was 9.15, which is the largest quantity that I have ever discovered in inflamed blood. The minimum was 3.4, and the mean of four analyses was 6.0. Andral and Gavarret found the maximum of fibrin to be 10.5: the minimum 4; and the mean to fluctuate between 7 and 8. They never met with more than 10.5 of fibrin in the whole course of their analyses.

The maximum of haemato-globulin, occurring in my researches, was 78, and the minimum 36, which is very far below the amount in healthy blood. Andral and Gavarret differ from me considerably on this point, (see my remarks on our comparative methods of analysis, page 200.) They make the maximum of the blood-corpuscles 137, and the minimum 83.7. We find, however, in the course of 58 analyses, made by them on the blood of 21 persons labouring under

¹ Lauer found that blood, which, as it flowed from the vein, had a temperature of 97°.7, raised the thermometer to 83°.6 thirteen minutes after its removal from the body.

pneumonia, that the amount of corpuscles just reached the normal proportion in 5 cases, in 6 cases exceeded it, and in the 47 remaining cases fell below it. The average of these cases was 113, which is 14 below the normal quantity in healthy blood, according to Lecanu's analysis.

The maximum of fat, in my analysis, was 4·3, and the minimum (in a man aged 60 years) was .7.

The maximum of solid residue was 202; the minimum was 160. In 51 out of the 58 analyses, made by Andral and Gavarret, the solid constituents exceeded the ordinary normal proportion.

In all these cases the quantity of the blood-corpuscles was very high: the fibrin, in two cases, reached 9·1; and in one case 9·0: in the others it was low, or amounted to only the mean of the fibrin in pneumonia.

The two highest amounts of solid residue found by Andral and Gavarret was 230, and 227; in these cases the maxima of corpuscles also occurred. The smallest amount of solid residue was 166, which corresponded with the minimum of blood-corpuscles. The mean quantity of solid residue, as deduced from these 58 analyses, was 201, or 9 less than Lecanu's average for healthy blood.

I have made four analyses of the blood in pneumonia:

	Analysis 19.	Analysis 20.	Analysis 21.	Analysis 22.
Water	839 848	798 500	803 179	803 400
Solid residue	160 152	201 500	196 821	196 600
Fibrin	9 152	6 030	5 632	3 443
Fat	2 265	4 100	4 336	0 697
Albumen	100 415	100 280	121 721	103 100
Globulin	34 730	74 880	52 071	74 948
Hæmatin	1 800	3 120	2 752	2 466
Extractive matters and salts	8 003	10 500	10 309	11 258
100 parts of hæmato-globulin con-	4 9	4 0	5 2	3 2
tained	} of colouring matter.			

The blood in analysis 19 was taken from a woman aged 40, who died a few days after the venesection. Dissections exhibited exudation, and tubercles in the lungs.

The blood in analysis 20 was taken from a vigorous man aged 30, who recovered; and in analysis 21, from a vigorous man aged 40, who also recovered.

The blood in analysis 22 was taken from a man 60 years of age, who suffered from cough, thoracic oppression, &c., and whose pulse was hard and full. I am ignorant of the result in this case.

The following are the maxima, minima, and average results, obtained by Andral and Gavarret:

	Water.	Solid residue.	Fibrin.	Corpuscles.	Solid residue of serum.
Maximum	834·4	229·5	10·5	137·8	95·2
Minimum	770·5	165·6	4·0	83·2	66·7
Average	799·0	201·0	7·3	114·1	81·0

The following table indicates the differences that are found in pneumonic blood during repeated bleedings. It is drawn up by An-

dral and Gavarret,¹ and corresponds generally with the table already given for the blood taken in a similar manner during bronchitis. It is, however, entirely at variance with Lecanu's statement regarding the blood in carditis. (See page 209.)

	Day of venesection. disease.	Water.	Solid residue.	Fibrin.	Corpuscles.	Solid residue of serum.
1st Case	1	818-0	182-0	40	111-3	66-7
	2	818-5	181-5	55	107-7	68-3
	3	820-9	179-1	65	101-1	71-5
	4	834-4	165-6	90	83-2	73-4
2d Case	1	773-0	227-0	52	137-8	84-0
	2	782-3	217-7	73	125-5	84-9
	3	795-0	205-0	69	117-4	80-7
3d Case	4	800-4	199-6	80	111-5	80-6
	5	781-5	218-5	55	129-8	83-2
	6	788-3	211-7	68	116-3	88-6
	9	823-9	176-1	64	95-7	74-0

This table is sufficient to show that the blood taken from the same individual in different consecutive bleedings varies considerably. The blood taken at the later bleedings contains less solid constituents, less blood-corpuscles, more fibrin, and more solid residue of serum² than the blood which is taken earlier.

This statement is, however, only true within certain limits; if the bleedings are carried beyond a certain extent, the fibrin, as well as the corpuscles, are diminished; the whole quantity of solid residue becomes less, whilst the residue of the serum increases. In the third case this proportion is seen on comparing the blood taken on the third, with that taken on the second bleeding; but it is much more strikingly shown in the analyses made by Andral and Gavarret, of the blood in acute rheumatism, as will be seen by the following numerical data.³

Bleeding.	Day of Disease.	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Solid residue of serum.
1	8	778-8	221-2	6-1	123-1	92-0
2	9	780-9	219-1	7-2	120-7	91-2
3	10	788-0	212-0	7-8	112-8	91-4
4	13	799-0	201-0	10-2	101-0	89-8
5	17	813-9	186-1	9-0	89-2	87-9
6	28	826-2	173-8	7-0	83-3	83-0

My own observations regarding the blood taken by repeated venesectiōns during peritonitis, give perfectly similar results. I shall endeavour to give an explanation of the origin of these changes at the end of the section on hyperinosis.

Dr. J. Davy⁴ has instituted numerous researches on the blood found in the body after death: in a case of pneumonia, he found a large quantity of fluid blood, clot, and fibrous coagula in the heart. The fluid portion did not coagulate after exposure to the air for 24 hours. In another instance, the fluid portion, when exposed to the air, coagulated rapidly and formed a buffy coat.

¹ *Annales de Chimie et de Physique*, vol. 75, p. 254.

² [This conclusion is not very obvious.]

³ *Edinb. Med. and Surg. Journal*, 1839.

⁴ Op. cit. p. 246.

[Dr. Rindskopf¹ has published several analyses of the blood in pneumonia.

1. A young man, with a very severe attack of pneumonia: delirium, and all the signs of arachnitis. After death a considerable effusion of pus was found on the membranes of the brain. Two venesectiōns were instituted during the last thirty-six hours. The first gave fibrin 5.470. The second analysis was more perfect, and yielded:

Water	-	-	-	-	-	828.566
Solid constituents	-	-	-	-	-	171.434
Fibrin	-	-	-	-	-	6.674
Albumen and blood-corpuscles	-	-	-	-	-	159.103
Soluble salts	-	-	-	-	-	8.302
Insoluble salts	-	-	-	-	-	1.107
Extractive matters	-	-	-	-	-	5.248

2. A man, aged 60 years, who had suffered for a considerable period from chronic bronchitis and emphysema, was attacked with broncho-pneumonia. The blood was taken shortly before his death, and contained, in 1000 parts:

Water	-	-	-	-	-	812.566
Solid constituents	-	-	-	-	-	187.434
Fibrin	-	-	-	-	-	12.796
Albumen and blood-corpuscles	-	-	-	-	-	160.300
Salts	-	-	-	-	-	10.930
Extractive matters	-	-	-	-	-	3.478

3. In the blood of a young man, aged 19 years, suffering from pneumonia, Rindskopf found:

	1st Venesection.	2d Venesection.
Water	775.448	783.944
Solid constituents	224.552	216.056
Fibrin	6.702	7.723
Albumen	79.021	65.744
Blood-corpuscles	122.097	120.682
Salts	9.201	10.416
Extractive matters	7.531	11.661

4. In a case of pneumonia after catarrh, four analyses were made, the blood taken at the first venesection apparently not having been examined. In addition to the bleedings, tartarized antimony and calomel were administered: recovery.

	2d Venes.	3d Venes.	4th Venes.	5th Venes.
Water	796.494	793.362	807.699	809.650
Solid constituents	203.506	206.638	192.301	190.350
Fibrin	5.919	7.715	10.384	8.155
Albumen and blood-corpuscles	173.605	169.883	165.960	160.522
Soluble salts	10.188	7.952		11.531
Insoluble salts	1.340	1.404	15.957	4.151
Extractive matters	11.454	19.684		5.991

5. In a case of pneumonia of four weeks' standing, accompanied with catarrh and delirium tremens, in which tartar emetic was administered, and recovery took place, the following results were obtained:

¹ Ueber einige Zustände des Blutes.

	2d Venesection.	3d Venesection.	4th Venesection.
Water	793-237	797-915	
Solid constituents	206-763	202-085	
Fibrin	7-893	9-087	9-478
Albumen and corpuscles	157-916	164-451	
Salts	10-978	8-291	
Extractive matters	29-975	20-250	

Heller¹ has analyzed the blood of a powerful young man, aged 21 years, suffering from pneumonia, the left lung being perfectly hepaticized.

The colour of the blood was rather dark. As it flowed from the vein, its reaction was perfectly neutral. The serum, after the separation of the clot, had an alkaline reaction, a specific gravity of 1025, and was of a darker yellow colour than usual, although the addition of nitric acid disproved the presence of biliphaein. The blood was composed of 600 parts of clot and 400 of serum. It contained, in 1000 parts:

Water	-	-	-	-	773-266
Solid constituents	-	-	-	-	226-744
Fibrin	-	-	-	-	4-320
Blood-corpuscles	-	-	-	-	145-574
Residue of serum	-	-	-	-	76-650

Becquerel and Rodier have analyzed the blood of five women suffering from pneumonia, two of whom were bled only once, while in three venesection was repeated.

The mean composition of the blood is expressed in the following table:

	1st Venesection.	2d Venesection.
Density of defibrinated blood	-	1059-6
Density of serum	-	1025-0
Water	-	801-0
Solid constituents	-	199-0
Fibrin	-	7-4
Fat	-	1-687
Albumen	-	61-1
Blood-corpuscles	-	122-5
Extractive matters and salts	-	6-4

The following salts were contained in 1000 parts of blood:

Chloride of sodium	-	-	28	31
Other soluble salts	-	-	27	24
Phosphates	-	-	0-308	0-445
Iron	-	-	0-493	0-512

Zimmerman² has found the specific gravity of the blood in this disease as high as 1065.

The following ultimate analyses of dried pneumonic blood has been recently published:³

¹ Archiv. für physiologische und pathologische Chemie und Mikroskopie. Wien, 1844. vol. 1, p. 3.

² Hufeland's Journal, 1843.

³ Hoffmann, Annalen der Chemie und Pharmacie, April, 1844. According to Macaire and Marçet (Mem. de la Société Phys. et d'Hist. Nat. de Genev., vol. 5, p. 223) healthy venous blood contains C 55-7, H 6-4, N 16-2, and O 21-7.

		Ash.	C.	H.
Blood buffed, 1st Venesection	-	4.365	57.438	8615
" 2d ditto	-	4.061	59.920	—
" 1st ditto	-	3.880	51.966	8643
" 2d ditto	-	3.784	51.149	7632

Two analyses of the blood in cases of pneumonia biliosa have recently appeared, one by Scherer, the other by Heller.

The individual whose blood was analyzed by Scherer was a robust young man, aged 29 years.

The clot was tolerably firm and tough, and covered with a greenish yellow buffy coat. The serum exhibited a similar tint, and nitric acid indicated the existence of biliphaein in the urine. The conjunctiva was coloured yellow, and there was considerable gastric disturbance.

The blood drawn at the first venesection yielded:

Water	-	-	-	-	779.00
Solid constituents	-	-	-	-	221.00
Fibrin	-	-	-	-	9.70
Blood-corpuscles	-	-	-	-	194.60
Albumen	-	-	-	-	72.26
Salts	-	-	-	-	9.57
Extractive matters	-	-	-	-	4.63

Blood was again taken, in consequence of further symptoms of congestion. It yielded:

Water	-	-	-	-	785.00
Solid constituents	-	-	-	-	215.00
Fibrin	-	-	-	-	9.40
Blood-corpuscles	-	-	-	-	122.96
Albumen	-	-	-	-	65.36
Salts	-	-	-	-	8.31
Extractive matters	-	-	-	-	9.67

Three days after this venesection the patient was again bled. The blood contained:

Water	-	-	-	-	780.00
Solid constituents	-	-	-	-	220.00
Fibrin	-	-	-	-	19.73
Blood-corpuscles	-	-	-	-	118.47
Albumen	-	-	-	-	69.63
Salts	-	-	-	-	7.63
Extractive matters	-	-	-	-	11.35

The blood obtained by a fourth venesection contained:

Water	-	-	-	-	796.00
Solid constituents	-	-	-	-	204.00
Fibrin	-	-	-	-	8.67
Blood-corpuscles	-	-	-	-	106.26

In Heller's case the blood was taken from a robust man, aged 31 years. The clot was firm, and slightly buffed; the serum was of a deep yellowish-red colour, very alkaline, of specific gravity 1023, and, on the addition of nitric acid, a blue coagulum was formed, indicative of the presence of biliphaein.

The blood consisted of 521 parts of clot and 479 of serum. It contained, in 1000 parts:

Water	-	-	-	-	-	781-659
Solid residue	-	-	-	-	-	218-361
Fibrin	-	-	-	-	-	6-113
Blood-corpuscles	-	-	-	-	-	147-114
Residue of serum (with bilipheuin)	-	-	-	-	-	65-124

Heller observes that he has often been able to detect bilipheuin in the blood of pneumonic patients when there have been no other indications of a disordered state of the hepatic functions.

In pneumonia venosa the buffy coat is absent. (Schönlein.)

γ. Pleuritis.

Never having analyzed pleuritic blood, I shall merely give the results obtained by Andral and Gavarret.

That the blood in this disease may exhibit considerable differences, will be seen by the following cases.

1st stage. Pleuritis in its early stage, before any effusion has occurred. In two cases of this nature, Andral and Gavarret found the quantity of fibrin increased to 5.8 and 5.9.

2d stage. Pleuritis not yet advanced, but effusion.

Andral and Gavarret found that the quantity of fibrin varied from 4 to 6 in eight cases of this nature.

3d stage. Pleuritic effusion of some duration; no fever. In four cases of this nature, in which effusion had occurred during well-marked pleuritis, from two to four months previously, the quantity of fibrin was increased, less certainly than in the preceding cases, but still in one instance rising as high as 4.8, and averaging about 4.

Hence it follows that the fibrin is increased in the blood in pleuritis, especially in the acute form, accompanied with fever; the increase, however, is not so decided as in pneumonia, bronchitis, and (as we shall presently see) in acute rheumatism.

Nasse¹ states that the buffy coat is particularly characteristic, and seldom absent in pleuritic blood.²

Andral and Gavarret's analyses gave the following results.

Venesection.		Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Solid residue of serum.
1st Case	1	774.2	225.8	5.9	127.7	92.2
2d "	1	789.4	210.6	5.4	90.4	114.6
3d "	1	845.6	154.4	5.0	68.3	81.1
4th "	1	782.0	218.0	5.2	122.9	89.9
5th "	1	815.0	185.0	5.0	91.5	88.9
6th "	{ 1	802.6	197.4	5.0	107.4	85.0
"	{ 2	807.6	192.4	5.0	102.5	84.9
7th "	1	833.1	166.9	4.1	84.7	78.1
8th "	1	763.3	236.7	4.9	141.1	90.7
9th "	1	861.3	198.7	4.8	120.8	73.1
10th "	{ 1	783.5	216.5	3.9	126.8	83.8
"	{ 1	780.3	219.7	5.8	118.9	96.0
11th "	1	816.9	183.1	3.8	92.8	86.5
12th "	{ 1	783.0	217.0	3.5	135.4	78.1
"	{ 2	798.5	201.5	4.2	124.2	73.1
Healthy blood		790.0	210.0	3.0	127.0	80.0

¹ Das blut, etc., p. 61.

² The buffy coat was absent 9 times in 35 cases in which blood was extracted during pleuritis, 3 times in 11 cases of pneumonia, and twice in 5 cases of bronchitis.

Lauer¹ states that he has found the serum turbid in pleuritis. Cauventou² analyzed the blood in a case of chronic pleuritis, accompanied with vertigo. It was turbid, of a dirty-red colour, and covered with a soft light-coloured buffy coat. The clot was moderately large, and floated in a yellowish-white, milky serum, which was perfectly neutral, devoid of smell or taste, coagulable by heat, but not by acids or alcohol, and scarcely at all by corrosive sublimate.

[Becquerel and Rodier have analyzed the blood of five men attacked with uncomplicated and acute pleuritis. The mean composition of the blood is given in the following table.

Density of defibrinated blood	-	1055-0
Density of serum	-	1026-0
Water	-	798-6
Solid constituents	-	201-4
Fibrin	-	6-1
Fat	-	1-905
Albumen	-	65-4
Blood-corpuscles	-	190-4
Extractive matters and salts	-	7-6

The salts consisted of:

Chloride of sodium	-	-	-	3-0
Other soluble salts	-	-	-	2-0
Phosphates	-	-	-	0-478
Iron	-	-	-	0-461

The blood-corpuscles and the albumen are considerably diminished, while the fibrin is increased.]

III. INFLAMMATION OF THE CHYLOPOIETIC VISCERA.

a. *Angina tonsillaris (amygdalitis.)*

Andral and Gavarret analyzed the blood of four persons suffering from angina vera, and they always found, in a greater or less degree, the distinctive characters of hyperinosis. They obtained the following results.

Venesection.	Day of Disease.	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Solid residue of serum.
1st Case	1	4	782-6	217-4	6-1	111-0
	2	5	793-6	206-4	7-2	105-3
2d Case	1	6	777-9	222-1	5-4	126-0
3d Case	1	2	819-5	180-5	4-4	90-0
	2	3	830-2	169-8	6-4	79-5
4th Case	1	-	779-6	220-4	3-8	190-3
Healthy blood		790-0	210-0	3-0	127-0	80-0

With the exception of the 4th case, which was one of chronic angina, and in which the blood presents no striking deviations from the healthy standard, and of the 2d case, in which the blood is extremely rich in solid constituents, the remainder exhibit a decided decrease

¹ Quidam de Sanguine diff., etc.

² Annal de Chim. et de Phys., vol. 39, p. 288.

in the quantity of the corpuscles,¹ and a less marked increase of friction.

β. Hepatitis and lienitis.

Accurate quantitative analyses of the blood in these inflammatory diseases are still wanted. It has been frequently observed that the proportion of fat is considerably increased in the blood during hepatitis, and Trail has found the serum milky on several occasions; Nasse² has occasionally seen it so highly coloured with biliphaein as immediately to tinge paper on being dipped in it; and Lauer³ has observed that a yellow-coloured sediment is deposited by the serum upon the buffy coat, during this disease.

In the milky serum to which we have adverted, Trail⁴ found 21·1% of solid constituents, which were composed of fatty oil 4·5, albumen 15·7, soluble matter 9. The water amounted to 78·9%. The specific gravity of the serum was 1·087; it was of a creamy consistency, and became thinner when exposed to a gentle warmth; when left to itself, even for weeks, it did not deposit any sediment.

In another instance the specific gravity was 1·025, and the solid constituents amounted to 15·2%, of which a considerable portion was oil.

The serum has been observed by Cullen, Testa, and Heusinger to be turbid in lienitis (Nasse.)

γ. Peritonitis.

The blood in peritonitis, and especially in the form denominated puerperal fever, exhibits in a tolerably well marked degree the characters of hyperinosis. I made two analyses of the blood of a patient suffering from peritonitis puerperalis, and found that the fibrin amounted to twice as much as in healthy blood. Andral and Gavarret obtained similar results.

My analyses yielded:

	Analysis 23.	Analysis 24.
Water	784·941	767·064
Solid residue	215·059	212·936
Fibrin	4·459	4·366
Fat	4·035	3·350
Albumen	107·406	109·714
Globulin	84·623	83·532
Hæmatin	3·691	3·733
Extractive matters and salts	10·350	9·440
The hæmato-globulin contained 4·0% of colouring matter. | The hæmato-globulin contained 4·2% of colouring matter.		

¹ In the blood obtained by the second venesection in Case 3, they fall even below the solid residue of the serum. Andral and Gavarret, however, attribute the low amount of corpuscles in this instance to the circumstance of the patient having been for some time under the poisonous influence of lead.

² Das Blut, etc., p. 78.

³ Quadrum de Sanguinis different. in Morbis, p. 34.

⁴ Edinb. Med. and Surg. Journal, vol. 17.

The blood in these analyses was taken from a woman aged 33 years, who, according to Dr. Ebert's report, exhibited the first symptoms of peritonitis on the evening of the second day after her confinement.

The belly was somewhat swelled, and tender to the touch. There was extreme heat, violent thirst, and rapid respiration. The pulse was quick, hard, and full, 130 in the minute. The blood formed a tolerably firm clot, and was covered with a buffy coat of a line and a half thick. There was violent exacerbation on the evening of the third day: the countenance was much flushed, there was delirium, the pulse was 140, and hard. It was at this period that the blood referred to in analysis 23 was taken.

On the fourth day the abdomen was tympanitic: the head-symptoms were comparatively gone: the countenance was pale, pulse 140, soft and small. The composition of the blood now taken is given in analysis 24. The patient died. Dissection showed that the thoracic organs were healthy, but that there was exudation in the abdomen, with flocculent and purulent matter: the same was found in the uterus and intestines. The vessels on the peritoneal surface were fully injected; and on cutting into the uterus, milky pus was observed to exude in pearly drops from the distended lymphatic vessels.

In relation to the chemical constitution of the blood taken at the second venesection, we may observe (*vide supra*, p. 215) that there is a diminution not only of the quantity of the solid constituents, but also of the hæmato-globulin or blood-corpuscles. The fibrin, however, instead of being increased, is diminished by .01, which may probably be accounted for by the circumstance of the pulse not having increased in frequency, and having even become less hard.

Andral and Gavarret¹ have made eight analyses of the blood of four persons suffering from peritonitis: one was a case of simple peritonitis; the others were instances of metroperitonitis. Two of the cases terminated fatally, and in these a large quantity of pus was found in the abdominal cavity.

Their analyses gave the following results:

Venesection.	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Solid residue of serum.
1st Case 1	787.2	212.8	5.5	129.8	84.5
2d "	1	822.9	177.1	5.4	88.3
	2	831.6	168.4	5.3	89.5
	3	851.0	149.0	3.6	60.5
3d "	1	786.4	213.6	7.2	117.0
4th "	1	789.4	210.6	3.8	120.0
	2	802.7	197.3	4.7	109.5
	3	813.5	186.5	6.1	100.3
Healthy blood	790.0	210.0	3.0	127.0	80.0

Andral and Gavarret make the following observations on these analyses. Two of them exhibited a considerable decrease² in the quantity of fibrin. In one of these cases (the third venesection of

¹ Annal. de Chimie et de Physique, vol. 75, p. 261.

² They do not, of course, refer to an absolute decrease below the healthy standard, but merely below the ordinary standard of the blood in inflammatory disorders.

the second case) it amounted only to 3·6 in 1000 parts of blood. The blood for this analysis was taken at a period when the patient was much reduced by marasmus.

Dissection revealed the existence of pus in the cavity of the abdomen, a consequence of the previous inflammation.

The second instance is that of the 1st venesection of the fourth case, in which 3·8 of fibrin were found. This case was that of a woman labouring under suppression of the catamenia, who was seized with violent pains in the abdomen, which were attributed to mere uterine congestion: there was no fever present. The blood contained 3·8 of fibrin, little more than the normal proportion. At the expiration of two days the pain became more acute, and the blood taken at the second venesection contained 4·6 of fibrin. From this rapid increase of the fibrin it was inferred (although there was no fever) that something more than simple hyperæmia of the uterus was present; and, in point of fact, on the following day all the symptoms of metroperitonitis were established.

At the third venesection, 6·1 of fibrin were found in the blood. After this time the patient began to improve.

This case is of much interest, as affording an illustration of the importance of chemical research in the formation and establishment of diagnosis.

[A singular case of peritonitis, in which milky serum was observed, has been recently published by Heller. It occurred in a robust but not corpulent man, aged 40 years. The blood, when first drawn, was of ordinary colour, and on standing, the clot and serum separated perfectly, the former not exhibiting a buffy coat.

In 1000 parts of blood there were:

Fibrin	- - - -	4·72
Blood-corpuscles	- - - -	80·13

In 1000 parts of the serum there were:

Water	- - - -	829·515
Solid residue	- - - -	170·485
Fat	- - - -	50·473
Albumen	- - - -	108·791
Extractive matters and salts	- - - -	11·221

The fat was perfectly saponifiable with potash, and yielded no traces of cholesterol.

After the separation of the clot, the serum exactly resembled milk: its reaction was alkaline, and its specific gravity 1024·35.

In the blood of a girl, aged 18 years, suffering from a slight attack of peritonitis, Becquerel and Rodier found a marked diminution of the blood-corpuscles, and an increase of the fibrin (5); the albumen remained normal, the phosphates and the cholesterol were increased.

The serum was abundant, limpid, and yellow; the clot large and firm.

In a woman, aged 24 years, attacked with metroperitonitis, Scherer observed a tolerably large buffy coat, apparently more gelatinous than tough. The clot was rather large, but not very firm. The serum was neutral.

The blood contained in 1000 parts:

Water	- - - -	814·53
Solid constituents	- - - -	185·47
Fibrin	- - - -	5·32
Albumen	- - - -	96·35
Blood-corpuscles	- - - -	70·16
Fat and extractive matters	- - - -	6·02
Salts	- - - -	713

Two days afterwards the blood contained:

Water	- - - -	832·58
Solid constituents	- - - -	167·42
Fibrin	- - - -	4·02
Albumen	- - - -	100·25
Blood-corpuscles	- - - -	52·30
Salts and extractive matters	- - - -	11·42

The buffy coat had a more gelatinous appearance, and the serum was redder than on the former occasion. Death occurred two days after the second venesection.

In a case of metroperitonitis, in which the blood was analyzed by Heller, the clot was soft, and exhibited a well-marked buffy coat. The serum was clear, but of a deep yellow colour, and contained a large quantity of biliphæin. Its specific gravity was 1024. The blood consisted of 486·5 parts of clot and 513·5 of serum, and contained:

Water	- - - -	890·02
Solid constituents	- - - -	179·98
Fibrin	- - - -	7·78
Blood-corpuscles	- - - -	87·12
Residue of serum (with biliphein)	- - - -	85·08]

IV. INFLAMMATION OF THE UROPOIETIC VISCERA.

Nephritis and cystitis.

Very little has been done in the chemistry of the blood in these diseases.

Lauer¹ found that the blood taken from a man suffering from nephritis, and who speedily fell a victim to the disease, strongly resembled milk.

Andral and Gavarret² analyzed the blood of a man suffering from inflammation of the bladder, and found it to be composed of

Water	- - - -	785·8
Fibrin	- - - -	5·4
Blood-corpuscles	- - - -	111·4
Solid residue of serum	- - - -	97·4

The increase of the fibrin and the diminution of the corpuscles

¹ Op. cit. p. 32.

² Op. cit. p. 266.

show that this blood is similar in its constitution to the blood in other inflammatory diseases.

The blood in acute rheumatism, erysipelas, tubercular phthisis, puerperal mania, &c., is so strongly impressed with the ordinary characters of hyperinosis, that we shall consider it in reference to those diseases, in the present place.

a. Rheumatismus acutus.

In acute rheumatism, accompanied by fever, the blood always exhibits, in a more or less marked degree, the characters of hyperinosis.

The clot is rather small, consistent,¹ and sometimes covered with a strong buffy coat. The serum is usually clear, and of a deep yellow colour.

I have made only one analysis of the blood in acute rheumatism accompanied with fever. I found that the quantity of fibrin was considerable, that the quantity of fat was sensibly increased, and of haemato-globulin much diminished in relation to the normal proportion.

Andral and Gavarret have analyzed the blood in 14 cases of acute rheumatism. They found that if the blood was taken during the period of acute pain and fever, the fibrin existed in much larger proportion than normal blood.

On the other hand, they found that the quantity of fibrin was even less than in normal blood, in the case of an individual who was bled after the subsidence of the pain and of the fever.

In those cases in which the pain and fever returned, after an improvement had taken place, an increase of fibrin was again observed.

My analysis gave the following results:

Analysis 25.		
Water	- - - -	801.500
Solid residue	- - - -	198.500
Fibrin	- - - -	6.320
Fat	- - - -	3.150
Albumen	- - - -	100.540
Globulin	- - - -	71.560
Hæmatin	- - - -	3.000
Extractive matters and salts		11.560

The blood was taken from a man aged 35 years, in whom the joints of the foot and knee were much swollen and very painful; the joints of the hand were less swollen, but very tender on being touched. The febrile symptoms were not severe.

The following table exhibits the maxima, minima, and mean of 43 analyses made by Andral and Gavarret upon the blood of 43 individuals suffering from acute rheumatism:

¹ Nasse states that, in inflammatory rheumatism, he has observed a solid clot, although, when the buffy coat was very strong, its consistence was less on its lower surface. According to Heller, a thick clot is formed in acute rheumatism. (Stark, Allg. Patholog. p. 950.) Jennings, on the other hand, maintains that the clot under the buffy coat is so loose as to fall to pieces on the slightest touch. (Course of Lectures on the Physiology and Pathology of the Blood, by Ancell. 'The Lancet,' 1840, p. 841.)

	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Residue of serum.
Maxima -	856	2284	102	1300	1046
Minima -	771.6	1604	98	701	769
Mean -	806.4	1946	6.7	1010	860
Healthy blood	790.0	2100	3.0	1270	800

100 parts of the solid residue of the serum gave, on an average, 7.9 of inorganic constituents.

The quantity of blood-corpuscles only once exceeded the quantity in normal blood, and this instance coincides with that in which the solid constituents generally attained their maximum, 228.0; in most instances it was considerably diminished, and hence we find that the average displays the corpuscles 16 below the ordinary proportion. In only four cases was the quantity of fibrin lower than 5.0. Andral and Gavarret remark that the acuteness of the pain seems to have a greater influence on the increase of the fibrin than the stage or duration of the disease. The blood will be found to contain as large a proportion of fibrin at the commencement of a rheumatic attack which begins very severely, as at a much later period in a case commencing mildly, but in which acute pain gradually supervenes. This will be seen by the following analyses:

Venesection.	Day of disease.	Water.	Fibrin.	Blood-corpuscles.	Residue of serum.
1st Case	1	4	797.1	8.9	1093
	2	5	796.9	9.8	1075
	3	6.	812.5	8.5	954
	4	10	820.6	6.4	935
	5	25	789.7	2.6	1179
2d Case	1	8	778.8	6.1	1231
	2	9	780.9	7.2	1207
	3	10	788.0	7.6	1126
	4	13	799.0	10.2	1010
	5	17	813.9	9.0	892
	6	28	826.2	7.0	838

In the first case, the maximum of fibrin is found in the blood taken at the second venesection, and as early as the fifth day of the disease. In the second case, on the contrary, it did not occur until the fourth venesection, upon the thirteenth day of the disease, when nearly all the joints were reported to be in a swollen and painful state. These symptoms began to diminish after the next two bleedings; the fever, however, still continued.

The minimum of fibrin in the first case occurred at the period of the fifth venesection, and in even less than the amount in normal blood: the corpuscles are now considerably increased. This venesection was performed on the eighteenth day of convalescence, after all pain had entirely disappeared, and after the patient had been put upon a nourishing diet.

Andral and Gavarret show in the following table how the remission of the fever influences the quantity of fibrin.

Venesection.	Day since commencement of disease.	Water.	Fibrin.	Blood-corpuscles.	Residue of serum.
1	4	795.0	6.2	111.9	86.9
2	19	801.5	3.7	102.0	82.6
3	24	814.9	5.5	96.8	83.9
4	34	833.8	5.8	81.5	78.9

The second bleeding was ordered when the fever had completely gone, and only a few slight pains remained; the third upon the occurrence of a relapse; and the fourth during a continuation of the pain and fever.

[Dr. Rindskopf has analyzed the blood of a woman suffering from rheumatism, accompanied with pneumonia. He found in 1000 parts:

	1st Venesection.	2d Venesection.
Water	809.973	
Solid constituents	190.027	
Fibrin	4.652	5.656
Matters coagulable by heat	166.954	
Salts	12.188	
Extractive matters	6.233	

Becquerel and Rodier have analyzed the blood of four men suffering from acute rheumatism. The mean composition of the blood is given in the following table:

Density of defibrinated blood	-	-	-	1055.5
Density of serum	-	-	-	1035.8
Water	-	-	-	798.9
Solid constituents	-	-	-	101.1
Fibrin	-	-	-	5.8
Fat	-	-	-	1.647
Albumen	-	-	-	66.9
Blood-corpuscles	-	-	-	118.7
Extractive matters and salts	-	-	-	8.1]

Andral and Gavarret have analyzed the blood of ten individuals suffering from chronic and subacute articular rheumatism. No peculiarly striking results obtained. The proportion of fibrin in no instance exceeded 5.0, and in two cases was as low as 2.9 and 2.6. The blood-corpuscles in one instance amounted to no less than 154.3, and the solid constituents to 259.1. In the other cases the corpuscles were below the healthy average.

These results lead us to the conclusion that, provided there are no other disturbing influences, as the rheumatism loses its acute character, the blood gradually throws off the specific characteristics of hyperinosis.

The following table exhibits the maxima, minima, and mean results, as deduced from 10 analyses:

	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Solid residue of serum.
Maximum	826.8	259.9	5.1	154.3	102.0
Minimum	741.1	173.2	2.6	79.0	77.1
Mean	792.7	217.3	3.8	108.2	95.2
Healthy blood	790.0	210.0	3.0	127.0	80.0

I add the results of some of the analyses, on account of the interesting remarks that Andral and Gavarret have made on them.

	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Solid residue of serum.
1	826.8	173.2	4.8	79.0	89.4
2*	818.3	181.7	4.6	89.1	88.0
3	815.4	184.6	4.0	88.6	98.0
4	741.1	259.9	2.6	154.3	103.0

The blood in the first of these cases was taken from a colour-mixer under the influence of lead, to which circumstance Andral and Gavarret attribute the deficiency of the corpuscles. In the second of these cases, the blood was taken from a person who had suffered from an acute attack of rheumatism, for which he had been bled six times (!), besides having had 200 leeches (!) applied; a fully sufficient reason why the blood contained only 89·0 of corpuscles. The blood in the third analysis was taken from a person suffering from incipient chlorosis. In the fourth case the blood was taken from a vigorous person, 20 years of age, which accounts for the unusually large quantity of corpuscles, as well as of solid constituents generally.

β. Erysipelas.

I have not made any analyses of the blood in erysipelas. Andral and Gavarret found that the blood, in ordinary erysipelas attended with fever, was so rich in fibrin, and the quantity of corpuscles so reduced, as to leave no doubt of the existence of hyperinosis.

It is by no means easy to detect the peculiar properties of the blood depending on this disease, for as soon as any inflammatory fever is complicated with it, the blood will, from that cause alone, assume a state of hyperinosis. Moreover, the mere circumstances of temperament, age, &c., may induce a state of the blood partially approximating to hyperinosis, or to hypnosis. Contradictory results may also arise from variations in treatment, as far as venesection is concerned. We know, for instance, that in France the lancet is used with an unsparing hand; and if venesection be ordered in a case of erysipelas in which no serious inflammatory affection is present, it is by no means impossible that the blood may exhibit the character of hypnosis. In Germany, on the contrary, venesection is seldom prescribed unless decided inflammatory symptoms present themselves; in this case the blood is sure to exhibit the character of hyperinosis. Schönlein states that in erysipelas the serum is always tinged yellow by the colouring matter of the bile; that the proportion of the serum to the clot is large; and that the consistence of the clot is inversely as its size.—These characters decidedly indicate a state of hyperinosis.

Andral and Gavarret have made eight analyses of the blood of five persons, four of whom were suffering from erysipelas of the face, and one from inflammatory erysipelas of the foot. In seven of these cases the fibrin was materially increased; in three instances it amounted to 5·0, in three to 6·0, and in one to 7·0. In a much shorter and milder case, in which there was but little fever, it amounted to only 3·6.

Their analyses gave the following results:

Venesection.	Day since commencement of disease.	Water.	Solid residue.	Fibrin.	Blood-Corpuscles.	Solid residue of serum.	
						organic.	inorganic.
1st Case	1	2	826·6	173·4	7·0	75·9	53·2 7·3
	2	3	836·0	164·0	6·1	64·4	57·3 6·2
2d Case	1	2	799·2	200·8	6·7	108·4	78·9 6·6
	2	3	806·2	193·8	7·3	101·9	78·2 6·4

Venesection.	Day since commencement of disease.	Water.	Solid residue.	Fibrin.	Blood-Corpuses.	Solid residue of serum.	organic. inorganic.
3d Case 1	3	831.2	163.8	5.0	73.6	83.0	7.2
4th " { 1	5	788.7	211.3	4.7	119.1	80.7	6.8
5th " { 2	8	796.9	203.1	5.0	110.7	80.5	6.9
5th " { 1	3	762.9	230.4	3.6	139.4	80.2	7.2

The large amount of corpuscles associated with the slight increase of fibrin in the fifth case is explained by the circumstance of the attack being very mild, and the constitution particularly strong. The reverse is seen in the first case, in which the blood was taken from a woman who had been scrofulous from her youth.

The serum contains, on an average, 7·8% of inorganic constituents; just the same amount as in acute rheumatism.

[Blood, in a case of erysipelas of the hand, analyzed by Rindskopf, yielded 7·71 of fibrin. The blood-corpuscles were not determined.

In a case of erysipelas in the face, occurring in a young man aged 20 years, recorded by Heller, the blood separated into 648·96 parts of clot and 351·04 of serum. The clot was tolerably firm, and covered with a buffy coat. The serum was of a fawn colour, and turbid, in consequence of suspended hæmato-globulin. It contained no bilirubin.

The blood contained in 1000 parts:

Water	-	-	-	-	-	762.44
Solid constituents	-	-	-	-	-	237.56
Fibrin	-	-	-	-	-	5.45
Blood-corpuscles	-	-	-	-	-	141.71
Solid residue of serum	-	-	-	-	-	90.40]

γ. Phthisis tuberculosa.

It is a well known fact that the blood of phthisical patients exhibits the ordinary characters of inflammatory blood.

The clot is usually rather small, consistent, and covered with a buffy coat: the serum is clear, and of a bright yellow colour. The blood differs considerably during the progressive stages of the disease.

Andral and Gavarret observe that, whatever be the stage of the disorder at which the blood is analyzed, the fibrin seems always on the increase, and the corpuscles on the decrease; but the proportion of the increase on the one hand, and decrease on the other, varies with the progress of the disease. If the tubercles are still in a crude, unsoftened state, the increase of fibrin is only small, and its whole amount may be estimated at about 4; and the decrease in the amount of corpuscles, although perceptible, is by no means great. As the tubercles begin to soften, the quantity of fibrin usually increases to about 4·5, while the amount of corpuscles continues on the decrease. Subsequently, upon the formation of vomicæ in the lungs, the fibrin rises to 5·5, and sometimes even to 5·9: it never, however, attains the height observed in pneumonia. In the very last stage of the disease, as the

blood becomes poor, the fibrin diminishes in much the same ratio with the other solid constituents, and sometimes falls even under the healthy standard. Generally speaking, it seems that the amount of fibrin attains its maximum about the period when the febrile symptoms are regularly established.

I have made three analyses of the blood of phthisical persons, the results of which are not devoid of interest.

	Analysis 26.	Analysis 27.	Analysis 28.
Water	807-500	825-200	750-000
Solid residue	192-500	174-800	250-000
Fibrin	4-600	6-500	a trace
Fat	2-350	4-200	3-750
Albumen	96-360	90-350	131-000
Globulin	71-230	61-110	94-500
Hæmatin	3-110	2-690	2-750
Extractive matters and salts	9-350	8-000	15-250

The blood in analysis 26 was taken from a man aged 36 years, in the second stage of tubercular phthisis, who afterwards sunk under the disease. The blood in analysis 27 was taken from a man aged 41, in the third stage of the disease, who suffered extremely from nocturnal colliquative sweats, and from feverish symptoms. In these two instances the blood exhibits the characters of hyperinosis, for the quantity of fibrin is in one instance twice, and in the other thrice the normal amount, and the amount of hæmato-globulin is below the healthy standard: moreover, the quantity of solid constituents is less than in healthy blood. Andral and Gavarret's observations respecting the changes that the blood undergoes as the disease advances are here borne out.

The 28th analysis gives results quite at variance with the two former. The blood in this instance was taken from a man about 30 years of age, who was treated in our hospital for tubercular phthisis. He had taken cod-liver oil for some time with much benefit; subsequently, however, frequent attacks of hæmoptysis came on, for which venesection was always immediately prescribed. The clot in these cases was seldom very firm. I analyzed the blood taken at his last venesection. It was received into a shallow vessel, and amounted to between six and seven ounces. It did not coagulate, and it presented the appearance of a homogeneous dark red fluid, in which some white gelatinous flocks of coagulated fibrin were swimming.

The blood contained, much to my surprise, a larger amount of solid constituents than I have ever observed in any other analysis. The fat, when isolated, smelt strongly of the volatile fatty acid of the cod-liver oil, the odour of which was also strongly developed during the evaporation of the blood to dryness. A considerable quantity of hæmaphæin was present, and deeply coloured the extractive matters and salts. It is very probable that the peculiar changes in the blood in this instance are due principally to the cod-liver oil and to the repeated bleedings.

Andral and Gavarret have analyzed the blood in 21 cases of this

disease. Their maximum of fibrin was 5·9, their minimum 2·1.— In only two instances did the amount of corpuscles approximate to the normal standard, as fixed by Lecanu. In these two cases it was represented by 122·1 and 120·4 respectively. The amount was frequently below 100, and the decrease of corpuscles was almost always found to be accompanied with a corresponding increase of fibrin.

The maxima, minima, and average of the various constituents, as deduced from 22 analyses, made by Andral and Gavarret, are given in the following table:

	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Solid residue of serum.
Maximum	845·8	225·0	5·9	122·1	105·4
Minimum	775·0	154·2	2·1	76·7	65·1
Mean	809·7	190·3	4·4	100·5	85·3
Healthy blood	890·0	210·0	3·0	127·0	80·0

This table shows the great difference that may exist between the quantities of the solid constituents, and of the corpuscles, in healthy and in diseased blood.

[Becquerel and Rodier examined the blood of nine persons affected with pulmonary phthisis, viz. five men and four women.

The following table represents the mean composition of the blood of the men:

	1st Venesection.	2d Venesection.	3d Venesection.
Density of defibrinated blood	1036·7	1055·5	1050·3
Density of serum	-	1028·0	1025·5
Water	-	794·8	821·0
Solid constituents	-	205·2	179·0
Fibrin	-	4·8	4·2
Fat	-	1·554	1·443
Albumen	-	66·2	65·0
Blood-corpuscles	-	125·0	122·7
Extractive matters and salts	-	7·7	6·7
			8·9

Mean composition of the blood of phthisical women:

Density of defibrinated blood	-	-	1055·4
Density of serum	-	-	1028·2
Water	-	-	796·8
Solid constituents	-	-	203·2
Fibrin	-	-	4·0
Fat	-	-	1·729
Albumen	-	-	70·5
Blood-corpuscles	-	-	119·4
Extractive matters and salts	-	-	7·6]

δ. *Febris puerperalis.*

[The blood in this disease has been analyzed by Heller: it was of a very dark brown colour, but coagulated in the ordinary manner: the serum was turbid, but after standing for some time became clear; its reaction was alkaline, its specific gravity 1025, and it contained no biliphæsin. The clot was dark, of a loose consistence, and covered with a strong buffy coat, over which there was a delicate membrane, that presented under the microscope a finely granular appearance, and fat-vesicles.

In 1000 parts of blood there were contained:

Water	- - - -	833-85
Solid constituents	- - - -	166-15
Fibrin	- - - -	5-16
Blood-corpuscles	- - - -	77-52
Albumen and extractive matters	- - - -	77-47
Fixed salts	- - - -	6-00

The blood has been partially analyzed in two cases of this disease by Becquerel and Rodier.

In the first case the blood, taken at the first venesection, yielded fibrin (4-3,) albumen (55-6,) and blood-corpuscles (77-3:) at the second venesection, the fibrin was, (4-2,) the albumen (54,) and the blood-corpuscles (66-6.) The cholesterin and the phosphates exceeded the normal amount.

In the second case, the fibrin was normal, the albumen (43,) and the blood-corpuscles (70.)]

a. Eclampsia. Convulsions.

[The blood of a girl, aged 20 years, who frequently had 40 or 50 attacks in the course of 24 hours, was subjected to several analyses by Heller.

The blood taken on the first occasion was of rather a dark colour, the clot was loose, and the serum was turbid and light red, in consequence of the presence of haematin. The specific gravity of the serum was 1030, and the relation of the clot to the serum as 446: 554.

The blood contained in 1000 parts:

Water	- - - -	797-00
Solid constituents	- - - -	203-00
Fibrin	- - - -	6-00
Blood-corpuscles	- - - -	92-36
Albumen with extractive matters	- - - -	96-03
Fixed salts	- - - -	8-35

A second venesection was instituted 33 days afterwards. The physical characters of the serum were much as on the former occasion, except that its specific gravity was only 1025. The blood was taken partly from the arm, and partly from the foot.

The blood from the arm separated into 598-4 parts of clot, and 401-6 of serum, and was composed of:

Water	- - - -	800-06
Solid residue	- - - -	199-94
Fibrin	- - - -	4-44
Blood-corpuscles	- - - -	113-16
Residue of serum	- - - -	82-35

The blood from the foot separated into 568-6 parts of clot, and 431-4 parts of serum, and was composed of:

Water	- - - -	778-43
Solid constituents	- - - -	221-57
Fibrin	- - - -	5-84
Blood-corpuscles	- - - -	125-30
Residue of serum	- - - -	89-93

In the blood from the foot, the clot was covered with a buffy coat of about two lines in thickness; in the blood from the arm there was no indication of that phenomenon.

Heller likewise analyzed the blood in a case of convulsions occurring a few hours after delivery.

At the period of the venesection there were symptoms of metrorrhagia and endometritis.

The blood was of a tolerably bright red colour, and separated on coagulation into 587.3 parts of clot, and 412.7 of serum. The specific gravity of the latter was 1026, and it contained a large quantity of biliphaein.

The blood contained in 1000 parts:

Water	-	-	-	-	789.20
Solid residue	-	-	-	-	211.80
Fibrin	-	-	-	-	5.87
Blood-corpuscles	-	-	-	-	124.07
Residue of serum	-	-	-	-	81.86]

γ. Carcinoma medullare colli uteri.

[The sanguineous discharge from the uterus of a woman, aged 34 years, presenting all the characters of intense anaemia, was analyzed by Dra. Lenzberg and Morthier. It was of a dark red colour, and the separation into clot and serum was not very perfect. There appeared, however, to be about 543 of the former, and 457 of the latter.

The blood consisted of:

Water	-	-	-	-	832.46
Solid constituents	-	-	-	-	167.53
Fibrin	-	-	-	-	16.44
Blood-corpuscles	-	-	-	-	77.03
Residue of serum	-	-	-	-	74.06

Here we see that there is an enormous increase of fibrin, and a great diminution of the corpuscles, while the residue of the serum remains almost normal.]

On the probable cause of the peculiar change in the composition of the blood in inflammatory diseases.

Although, in consequence of the deficiency of our knowledge regarding the true nature of inflammation, an attempt to explain the primary causes of the change undergone by the blood during this process may be deemed precipitate, yet the announcement of an opinion (though it have no higher claim than a mere hypothesis) may be of service in directing the attention of other investigators to the subject.

Numerous observations have shown us that blood retained for any length of time in an organ, and thus prevented from meeting with a due supply of oxygen, becomes poorer instead of richer in fibrin; whereas there is undoubted evidence that in inflammation the fibrin is increased. Moreover, blood impeded in the course of the circula-

tion becomes darker, (a sign that there is not a due supply of oxygen,) while blood in inflammation is generally brighter than in the normal state. The solid constituents of inflamed blood are certainly diminished, but the increased amount of fibrin renders it more plastic; so that we are not justified in comparing it (as Magendie has done) with blood in which the capacity of coagulation has been lessened by water, or alkaline carbonates, and which produced in the various organs, symptoms resembling those of inflammation. This defibrinated blood presents characters entirely the reverse of what we observe in inflammatory fluid, and resembles the condition of the circulating blood in typhoid fevers. We can, I think, scarcely doubt that the blood in an inflamed organ differs in its composition from the blood in the rest of the body, provided we can assume that there is a stagnation of the blood in the affected organ during the whole period of inflammatory action.

Whether the blood is the first part of the system that becomes diseased, or whether it becomes modified in consequence of the pathological condition of the suffering organ, is a question not easily answered. This much, however, is certain, that whatever be the inflamed organ, the blood invariably differs from its normal condition in the same manner, although with varying intensity. If we direct our attention to the reaction of the whole organism during inflammation, we see that all the organs essential to the well-being of the blood are disturbed; the temperature of the whole body is heightened; the pulse is full, hard, tense, and frequent; the urine scanty and loaded. Under all these circumstances we must expect to find a considerable deviation of the blood from its normal condition.

If, in this general reaction of the whole system, which corresponds with a heightened amount of vitality in the blood, a more rapid circulation is induced, we shall, without much difficulty, be enabled to give a sufficient explanation of the manner in which the peculiar changes already adverted to, are brought about.

The vital activity of the blood is heightened, and its metamorphosis hastened, by an increased rapidity of the circulation; it remains, then, for us to consider what effect an accelerated metamorphosis will have on the composition of the blood.

The metamorphosis of the plasma during the process of nutrition in the peripheral system will not necessarily be increased by an accelerated circulation; since (as I have endeavoured to show, in page 128,) the plasma remains virtually passive, and is only changed by the cells of the organs, through which it passes, possessing the inherent power of abstracting and appropriating from it the substances requisite for their nourishment. It is different, however, with the active metamorphosis of the blood, in which the corpuscles are changed at the expense of the plasma. If the general circulation be hastened, the blood will be urged more frequently through the lungs and other organs that exert a modifying influence on its composition.

Hence the blood (passing more frequently through the lungs) gives off a larger amount of carbon in the form of carbonic acid than in the normal condition. If, as I have endeavoured to show (pp. 133 and 183,) the blood-corpuscles take an essential part in the respiratory process, and their vital activity, evolution, and revolution are only carried on with the co-operative agency of the atmospheric origin, then, in proportion to this increased co-operation, will their development be hastened, their vitality heightened, and more corpuscles be consumed than in the normal state.

Two important conclusions may be drawn from my theory, regarding the production of fibrin from the blood-corpuscles, viz. that the amount of fibrin is increased, and of blood-corpuscles diminished. This is the more striking, since the increase of fibrin during the development of the corpuscles does not keep pace with its consumption in the act of peripheral nutrition, and since the supply of blood-corpuscles afforded by the chyle cannot be proportionate with the diminution produced by the accelerated circulation.¹

Hence, if we only assume that the circulation is increased by the reaction of the organism in inflammatory affections, an explanation is at once afforded us of the change that occurs in the composition of the blood in hyperinosis, and at the same time of its heightened temperature. We do not, however, mean to imply that the increased circulation is the sole cause of the change in the blood, for it can hardly be denied that the nerves exert an influence on its constitution; moreover, as we have already shown, venesection modifies its characters.

SECOND FORM OF DISEASED BLOOD: HYPINOSIS.²

I have shown, in speaking of hyperinosis sanguinis what striking changes in the blood are due to the excessive accumulation of fibrin, and a corresponding diminution of blood-corpuscles. These differences are easily seen, because it is usually necessary that blood should be taken at a period when these changes are most obvious. In hypnosis sanguinis the case is different: in many diseases of this nature it is not customary to abstract blood at all, or at any rate only when an inflammatory affection is also present. Its distinctive characters are therefore seldom so decidedly marked as in the former case, and, in point of fact, less is known regarding this form of diseased blood.

Chemical characters of the blood.

The quantity of fibrin is frequently less than in healthy blood, or if it amounts to the normal quantity, its proportion to the blood-cor-

¹ It has been suggested that blood in which there is an excess of fibrin increases the energy of the heart's action, while blood deficient in fibrin diminishes it. The rapid circulation of the blood in inflammations and its torpid condition in certain typhoid affections seems in favour of this view.

² Formed from ὕπνος and τρόπος, the fibre of flesh.

puscles is less than is found in a state of health (2·1: 110 *Simon*, or 3: 110 *Lecanu*;) the quantity of corpuscles is either absolutely increased, or their proportion to the fibrin is larger than in healthy blood: the quantity of solid constituents is also frequently larger than in the normal fluid.

Physical characters of the blood.

The clot is most commonly large (but sometimes small,) soft, diffluent, and of a dark, almost black red colour: occasionally no clot is formed. The buffy coat is seldom seen, and when it does occur it is thin and soft, or forms a gelatinous parti-coloured deposit on the clot. The serum is sometimes of a deep yellow tinge, from the colouring matter of the bile, or red, from blood-corpuscles in suspension; the blood has always an alkaline reaction.

From the numerous analyses of Andral and Gavarret, and from the observations of others, it appears that the blood occurs in a state of hypnosis in fever; if, however, the reaction assumes the synochal type, or if inflammation of the respiratory or other organs supervene, then the fibrin will increase in a corresponding degree, and the blood-corpuscles decrease, so that the blood will approximate in its constitution to the normal standard, or even partially assume the characters of hypernosis.

a. *Typhus abdominalis.*

The blood in this disease exhibits the characters of hypnosis perhaps more distinctly than in any other affection: but the statements regarding its qualitative and quantitative composition are still very contradictory, arising, probably, in part, from its varying in different stages of typhus: thus, in the period of excitement, it may incline towards a state of hypernosis; in the stage of depression, the fibrin gradually decreases; and lastly, in the stage of collapse, the quantity of blood-corpuscles and of solid constituents decreases so remarkably, that in the case of putrid abdominal typhus the blood (in consequence of the liquor sanguinis being too watery, and deficient in salts) assumes the state of spanæmia. The same appears to occur in petechial typhus.

One source of difference is therefore evidently dependent upon the stage of the disease at which the blood is taken: the presence of any inflammatory symptoms will also modify its constitution.

The blood in typhus is found to be very deficient in fibrin, and frequently also in albumen: it coagulates imperfectly, and often remains in a semi-fluid state: the clot is soft, friable, of a very dark, almost black red colour, and is very rarely covered with a buffy coat: this form of blood becomes putrid sooner than the healthy fluid.

I have made two analyses of the blood in rather mild forms of the disease. The results do not by any means give a good idea of hypnosis sanguinis.

	Analysis 29.	Analysis 30.
Water	816.875	792.340
Solid residue	183.125	207.660
Fibrin	2.525	2.010
Fat	2.233	2.200
Albumen	90.650	80.330
Globulin	75.205	99.510
Hæmatin	3.985	5.300
Extractive matters and salts	9.678	12.670

The disease diagnosed in both instances (which occurred in our hospital) was dothenteritis.

In both cases venesection was ordered at an early stage of the disease, when there was a good deal of vascular excitement present, which may account for the partial decrease of the fibrin and increase of the corpuscles.

The blood in analysis 29 was taken from a man 30 years of age; the tongue was furred, abdomen tender on pressure, mind tolerably clear; pulse rather full, 95 in the minute.

The blood in analysis 30 was taken from a man 38 years of age; in whom there was a good deal of nervous excitement, giddiness, and buzzing of the ears; the abdomen was tender on being pressed, the tongue thickly coated, and the pulse quick, rather hard and full. Both cases turned out favourably.*

The most comprehensive researches on the blood in typhoid fever (*fièvres typhoides*)² are those of Andral and Gavarret, who made 50 analyses of blood taken from 20 persons suffering under this affection.

The following are their principal results:

The fibrin never rises perceptibly above the normal standard in true typhoid fever. It often remains at the normal height, and is still more frequently below it.

In inflammatory disorders it is pretty clear that the fibrin increases with the intensity of the disease; here we observe just the reverse: the fibrin decreases in proportion to the advancement of the disorder.

Andral and Gavarret observe that this cannot be ascribed to the repeated bleedings, or to the continual low diet, for these circumstances induce no change in the amount of fibrin in other diseases. As soon, however, as any symptoms of convalescence appear, the fibrin begins to increase, even before the organization could contribute a supply by increased nutriment. This continues to be the case during the progress of convalescence, and as the patient improves the corpuscles simultaneously decrease.

In inflammatory diseases we observed a general tendency to diminution in the corpuscles: here we have just the reverse, for the more frequently we analyze blood soon after the outbreak of the

* [In an analysis of the blood in typhus abdominalis, made subsequently to the publication of his Chemistry, Simon found, water 887.5, solid constituents 112.5, fibrin none, albumen 54, hæmato-globulin 47.25.]

² Fièvre continue qui reconnaît pour caractère anatomique l'inflammation exanthématuse, puis ulcèreuse, des follicules intestinaux. (Andral.)

disease, the more frequently shall we find instances in which the corpuscles, instead of being diminished, are considerably increased, and, even in the more advanced stages, the amount of the corpuscles is frequently found to exceed, or at any rate to equal, the normal quantity.

The absolute increase of the corpuscles is not, however, so decided as the increase of the fibrin in inflammatory diseases; neither is it so essential a condition for the existence of the disease, for even in those cases in which the amount is much increased at the commencement of the disorder, it may become diminished during its course, and even when it is getting more severe. However, when the absolute quantity of the corpuscles is diminished, its proportion to the fibrin is still greater than is ever observed in the normal state.

The leading characteristic of the blood in this disease is the decrease of the fibrin, which diminishes in proportion to the violence of the attack, and from which another character is derived, namely, the increased amount of corpuscles. During the early period the diminution of the fibrin is not absolute; it is only relative in relation to the corpuscles; but as the disease approaches its height, the diminution becomes absolute.

Researches instituted in mild cases may give perfectly negative results.

Their maximum of fibrin was 3·7; their minimum .9. It is true that in one case they found 4·2 of fibrin, but the blood was taken during convalescence.

The maxima, minima, and average results of 41 analyses are given in the following table:

	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Solid residue of serum.
Maximum	- -	862·3	243·7	4·2	149·6
Minimum	- -	756·3	137·7	0·9	66·7
Average	- -	796·0	204·0	2·6	116·0
Healthy blood	-	790·0	210·0	3·0	127·0
					80·0

This average of 41 analyses (I have omitted some, as giving no definitely clear result) does not give the general characters of the blood, as it is expressed in the majority of the analyses. The amount of fibrin is certainly less than in healthy blood, but the corpuscles do not attain to their normal height. If, however, the fibrin is estimated at 3·0, the proportion of the corpuscles is 134, which is higher than in healthy blood.

The quantity of the residue of the serum, and of solid constituents generally, approximates closely to the normal standard.

The inorganic constituents of the residue of the serum amount, on an average, to 7·6%, which is very little lower than the corresponding number in erysipelas or rheumatism.

Reid Clanny states, however, that the quantity of salts is materially diminished in typhoid blood.

The following table contains the numerical results of Andral and Gavarret's researches on the blood in typhoid fever. In order to

make the proportion of the corpuscles to the fibrin more striking, I have given not merely the numbers obtained from the analyses, but the relative numbers on the assumption that the fibrin is constantly represented by 3.

Venesection.	Date of attack.	Water.	Solid constituents.	Fibrin.	Blood-corpuscles.	Blood-corpuscles. (Fibrin = 3.)	Residue of serum.
1st Case	1	5	756-3	243-7	2-3	145-3	180-0
	2	7	769-7	230-3	2-1	135-8	193-0
	3	8	785-2	214-8	1-8	126-2	210-0
	4	10	798-6	201-4	1-3	116-2	268-0
	5	15	827-4	272-6	1-0	91-7	273-0
2d "	1	?	819-7	180-3	0-9	93-1	310-0
3d "	1	5	752-9	247-1	2-4	146-7	183-0
4th "	1	7	766-5	233-5	2-5	143-6	172-0
	2	9	777-6	222-4	3-7	136-2	110-0
	3	12	789-1	217-9	3-6	134-5	112-0
5th "	1	8	767-6	232-4	5-0	139-3	83-0
	2	10	777-3	222-7	5-4	129-7	72-0
	3	11	782-4	217-6	5-0	127-1	76-0
	4	14	791-7	208-3	4-0	123-6	92-0
	1	9	769-5	230-5	3-6	149-6	124-0
6th "	2	10	784-7	215-3	2-9	125-3	129-0
	3	12	804-3	195-7	2-3	123-7	161-0
	4	15	831-1	168-9	1-9	103-0	163-0
7th "	5	33	845-5	154-5	3-7	79-6	64-0
	1	9	810-3	189-7	3-4	102-4	71-2
	2	10	816-2	183-8	3-5	105-0	90-0
	3	12	825-6	174-4	2-3	93-9	122-0
	4	17	836-8	163-2	1-7	86-3	152-0
	5	24	847-8	152-2	2-1	76-0	108-0
							74-6

From these two columns of the blood-corpuscles we see that the decrease of the fibrin is almost always connected with the increase of the corpuscles, so that the proportion between the two gradually differs more and more from the normal mixture.

The exceptions to this rule are caused either by some inflammatory complication, as in the fifth case, where an acute attack of bronchitis accompanied the fever, or by the patient being in a state of convalescence as in the fifth analysis, in cases 6 and 7.

Andral and Gavarret offer no explanation of the peculiarities in the fourth case.

The solid constituents of the blood are more frequently above than below the normal standard, but the proportion is a fluctuating one, and dependent, as we shall presently see, on the progress of the disease.

Lecanu has analyzed the blood of two persons suffering from typhoid fever. As he did not determine the amount of fibrin, the proportion of that constituent to the corpuscles cannot be shown. Their absolute quantity is less than in normal blood. Lecanu also states, that he thinks that a paucity of corpuscles may be inferred from the smallness and friability of the clot,¹ a statement at variance with the researches of Andral and Gavarret.

¹ I may take this opportunity of saying a few words regarding the possibility of drawing a correct inference respecting the amount of fibrin and of corpuscles from the clot. We are

Lecanu also found a diminution of the solid constituents generally:—

Water	-	-	-	805.20	795.68
Solid residue	-	-	-	194.80	204.20
Blood-corpuses	-	-	-	115.00	105.00
Residue of serum	-	-	-	79.00	99.12

Chomel does not consider that the diminution of fibrin is a specific character of the blood in typhoid fever, because he found that in 6 out of 30 cases the blood formed a solid clot, covered with a buffy coat, but differing in thickness and colour from the inflammatory clot; while in 2 cases there was a slight film, beneath which the clot was diffuent, in 2 the blood remained perfectly fluid and slightly lumpy, and in 20 the blood formed a firm clot, but no buffy coat.

The blood in all these cases was taken during the first or the commencement of the second stage, never in the third. The peculiarities in Chomel's statement may be partly due to the blood being taken at a period before the fever had reached its height, partly to the association of some inflammatory symptom, or to a more synochal type of the disease.

According to Jennings,¹ the blood in the first stage of typhoid fever (depression) is generally thick and dark; it coagulates rapidly and forms a soft, large, dark-coloured clot. In the second stage (excitement) it flows readily, is of a scarlet colour, does not coagulate so quickly as, and forms a more solid clot than the former. It is also occasionally covered with a slight buffy coat. In the third stage (collapse) it flows very readily, is thin, watery, and of a dark colour: the clot is loose and flocculent, and occasionally appears more as a sediment of colouring matter than as a clot. In thoroughly developed typhus, Dr. Armstrong found the blood of the temporal artery as dark as that of the vein. Dr. Clanny also states that the watery portion of the blood increases with the intensity of the disease, and that not merely the solid constituents generally, but also the salts and carbonic acid are diminished. The water begins to decrease, and the solid constituents to increase in favourable cases after 12 or 18

justified in assuming the existence of a great quantity of fibrin from a large and very firm clot, and a small amount from a small diffuent clot. We cannot, however, with the same accuracy, draw similar inferences respecting the amount of corpuses. On receiving the blood of a cachectic horse into a high cylindrical glass and into a shallow vessel, a large and very firm clot generally forms in the latter (unless, as is sometimes the case, the blood-corpuses sink during coagulation,) and little serum is expressed; while, in the other vessel, two distinct layers are observed, a large one, consisting of firmly coagulated fibrin, containing serum, below which there is a much smaller layer, consisting of semifluid blood-corpuses. As the albumen enclosed in the coagulated fibrin in the high glass forms a very solid mass resembling a pseudopolypus or buffy coat, we see that, independently of the corpuses, a very firm clot may be formed; indeed, in inflammatory blood, this is often observed to a greater or lesser degree. There may, consequently, be as many blood-corpuses in a small and loose clot as in a large and firm one; moreover, we usually find numerous corpuses suspended in the serum and deposited at the bottom of the vessel, in addition to those contained in the clot, in blood deficient in fibrin. The relative amount of corpuses and of fibrin in clots of different size and consistence is a subject worthy of investigation.

¹ Course of Lectures on the Physiology and Pathology of the blood, by H. Ancell. The Lancet, 1840, p. 338.

days. According to Stevens, the salts of the blood (especially the chloride of sodium) are diminished in all typhoid fevers.

[Becquerel and Rodier have analyzed the blood of 13 persons attacked with typhoid fever, 11 men and 2 women. Of the 11 men, 6 were bled once, 4 twice, and 1 thrice; of the two women, 1 was bled once, and 1 thrice.

The following table exhibits the mean composition of the blood of the male patients, obtained at the first venesection:

Density of defibrinated blood	-	-	-	-	1054·4
Density of serum	-	-	-	-	1025·4
Water	-	-	-	-	797·0
Solid residue	-	-	-	-	203·0
Fibrin	-	-	-	-	2·8
Fat	-	-	-	-	1·773
Albumen	-	-	-	-	64·8
Blood-corpuscles	-	-	-	-	127·4
Extractive matters and salts	-	-	-	-	63

The salts consisted of:

Chloride of sodium	-	-	-	-	2·9
Other soluble salts	-	-	-	-	2·5
Phosphates	-	-	-	-	0·497
Iron	-	-	-	-	0·555

The fibrin varied considerably, the maximum being 4·9, while in three cases it was considerably below the normal standard. The albumen and blood-corpuscles were, in most instances, diminished.

Four of the same men were bled a second time, and the following table gives the mean results of the blood obtained in these four cases, on both occasions:

		1st Venesection.	2d Venesection.
Density of defibrinated blood	-	1054·0	1051·4
Density of serum	-	1025·0	1024·7
Water	-	801·0	814·5
Solid constituents	-	199·0	185·5
Fibrin	-	2·3	1·3
Fat	-	1·527	1·408
Albumen	-	64·4	62·0
Blood-corpuscles	-	124·5	113·6
Extractive matters and salts	-	6·0	7·3

The salts consisted of

Chloride of sodium	-	-	3·6	3·5
Other soluble salts	-	-	2·6	2·7
Phosphates	-	-	0·544	0·555
Iron	-	-	0·581	0·519

A comparison of the two columns shows that the blood obtained by the second venesection contains a considerably smaller mean amount of fibrin than the blood previously taken. The albumen and corpuscles are likewise diminished.

The case in which venesection was performed three times offered no peculiarity; neither did the analyses of the blood of the two women.

In all these analyses the clot was found to present no striking pe-

culiarity. There was none of the softness and diffuseness on which the older writers laid so much stress.

Scherer has analyzed the salts of the blood in a case of typhoid fever. In 1000 parts of blood there were 176·3 of solid residue, which on incineration yielded 11·92 of fixed salts. These consisted of:

Chloride of sodium	-	-	6·82
Carbonate of soda	-	-	1·41
Sulphate of soda	-	-	0·84
Phosphate of soda	-	-	0·94
Carbonate of lime	-	-	0·16
Phosphate of lime	-	-	0·60
Sulphate of lime	-	-	0·22
Peroxide of iron	-	-	0·60]

3. *Febris continua.*

1. *Prodromi febris continua.* The blood exhibits similar changes in the progress of continued fever, as in typhus. Andral and Gavarret have carefully analyzed the blood in this disease, and give the following account of their researches.

They made nine analyses of the blood of six persons. The fibrin did not exceed the normal amount in any instance, (in one, however, it amounted to 3·2;) in three cases it was a little below the standard, but exceeded 2; in two cases it was rather less than 2; and in one case as low as 1·6. The amount of blood-corpuscles was lower in only two cases than in normal blood; in the others it was more or less increased, and in the blood in which the fibrin amounted to only 1·6, the corpuscles amounted to 157·7, which, if the fibrin were estimated at 3, would give the enormous amount of 296. We have only one instance in typhoid blood of so high a proportion. The amount of the residue of the serum is increased, rather than diminished, and the same is the case with the solid constituents of the blood generally.

Their analyses gave the following results:

Venesection.	Date of the disease.	Water.	Solid residue.	Fibrin.	Blood- corpuscles.	Residue of serum.
1st Case	1	7	766·2	239·8	3·0	143·6
2d " "	1	8	769·5	230·5	1·8	136·4
3d " "	1	8	761·3	238·7	2·9	149·7
4th " "	15	770·8	229·2	3·2	137·9	89·1
5th Case	{ 1 2 3	785·6 788·3 790·8	213·4 211·7 208·2	2·3 2·2 2·1	125·4 194·0 123·0	86·7 86·3 84·1
6th Case	{ 1 2	744·2 779·7	255·8 220·3	1·6 2·1	157·7 139·3	96·6 88·9

The inorganic constituents of the residue of the serum amounted on an average to 7·5%, which corresponds with the proportion in typhoid fever.

2. *Febris continua.* Andral and Gavarret made 21 analyses of the blood of 11 persons suffering from continued fever. They divide their analyses into two series, one containing the results ob-

tained when the blood was taken nearly at the termination of the disease; the other, when certain inflammatory states, as for instance angina, bronchitis, erysipelas, &c., had supervened.

These researches exhibit less of the characters of hypnosis than those instituted on the blood at the commencement of continued fever, which, in the first series may be due to the circumstance of the disease being on the decline; and in the second, to the inflammatory complication.

In both series the fibrin exceeds the normal amount, and in both, the amount of corpuscles is, in part, also below the standard.

The following analyses are taken from the first of these tables:

Venesection.	Date of disease.	Water.	Fibrin.	Blood-corpuscles.	Residue of serum.
1st Case	1	725.6	3.3	185.1	86.0
	2	789.3	3.3	129.3	79.1
	3	824.9	3.2	82.5	89.4
2d "	2	833.7	3.1	77.2	86.0
	3	851.9	4.2	62.4	81.5

The blood in the first of these cases was taken from a man aged 58 years. The amount of the corpuscles, especially when the age of the patient is considered, is very surprising; it is the highest amount ever found by Andral and Gavarret. In the second case, the patient was at the same time suffering from chlorosis, which accounts for the small number of corpuscles.

The second table does not give very clear results, on account of the inflammatory complications.

Venesection.	Date of disease.	Water.	Fibrin.	Blood-corpuscles.	Residue of serum.
1st Case	1	793.8	4.3	114.7	87.2
	2	801.9	3.6	109.8	85.0
	3	810.0	5.0	95.9	89.1
2d "	1	758.9	3.8	160.7	76.6
3d "	1	784.2	2.6	131.0	83.2
4th "	1	804.8	5.4	94.1	95.7
5th "	1	791.4	3.1	118.6	86.9
	2	810.1	4.0	101.8	83.1
	3	824.3	3.7	86.9	85.1

In the first of these cases the fever was complicated with a rather severe attack of angina. In the third analysis in this case, the blood contained a large quantity of fibrin due to a renewal of the inflammatory symptoms in a rather violent form. Slight erysipelas of the face was present in the second case; in the third there was swelling and redness of the tonsils; in the fourth the fever was complicated with acute bronchitis; in the fifth the blood was taken from a woman three months after delivery: at the period of the second venesection, some slight symptoms of meningitis had appeared.

Jennings¹ has analyzed the blood of a girl aged 14 years, suffering from continued fever. He found it composed of:

Water	-	-	-	856.0
Solid residue	-	-	-	144.0

¹ Course of Lectures on the Physiology and Pathology of the Blood, by H. Ancell. The Lancet, 1840, p. 339.

Fibrin	-	-	-	2·0
Fat	-	-	-	3·0
Albumen	-	-	-	37·0
Blood-corpuses	-	-	-	91·0
Extractive matter	-	-	-	3·0
Alkaline salts	-	-	-	3·8
Earthy salts	-	-	-	1·0

[Becquerel and Rodier have analyzed the blood of 3 men and 2 women suffering from ordinary continued fever. The mean composition of the blood of the 3 men is given in the following table:

Density of defibrinated blood	-	-	-	-	1056·8
Density of serum	-	-	-	-	1026·5
Water	-	-	-	-	781·6
Solid constituents	-	-	-	-	2184
Fibrin	-	-	-	-	2·8
Fat	-	-	-	-	1·7
Albumen	-	-	-	-	65·7
Blood-corpuses	-	-	-	-	1424
Extractive matters and salts	-	-	-	-	5·8

Here we see that the fibrin and albumen remain nearly normal, while the corpuscles, instead of diminishing, are slightly above the average (their numbers being 146, 142, and 138.) The fatty matters and salts offered no peculiarity.

They give the following particulars regarding the blood of the two female patients.

The corpuscles were augmented (135·5) in the first case; normal (125·5) in the second: fibrin normal (1·9) in the first; doubled (3·6) in the second: albumen normal (73 and 70) in both. The serum was turbid in both cases. In the case in which the corpuscles were 125, the clot was firm and resisting, in the other it was soft and diffluent.]

In the following exanthemata, which, with true erysipelas, constitute Schönlein's family of *Erysipelacea*, we find that the composition of the blood is very similar to what it is in continued fever; the characters of hypnosis are much less marked than in the typhoid form. Some analyses give negative results, while in others the tendency of the constitution of the blood is more towards hyperinosis than hypnosis.

The maximum of fibrin amounts to only 4·4, against which there is a minimum of 1·1. In the majority of cases it does not differ much from Lecanu's normal average 3.

The blood-corpuses are increased in a less degree in variola and varioloid, than in scarlatina and rubeola.

Variola et morb. varioloid.

The blood was analyzed by Andral and Gavarret in 5 cases of true variola and 2 of varioloid disease.

In all the cases of variola the eruption was confluent. The blood-

corpuscles differed but little from their normal standard, but the quantity of fibrin varied considerably, although the increase above the normal mean was only small. It is worthy of remark that the quantity of fibrin appears to increase, although only slightly, by repeated bleeding; a circumstance which, according to Andral and Gavarret, characterizes the phlogoses.

This may be due to the inflammatory state of the skin in this disease, although we do not perceive a similar occurrence in typhoid fever, in which the mucous surface of the intestine is in a somewhat similar state.

Their analyses gave the following results:

Venesection.	Water.	Fibrin.	Blood-corpuscles.	Residue of serum.
1st Case	1 2 3	771.5 780.8 820.2	4.4 2.9 3.2	120.6 110.2 94.6
	1	791.3	3.0	114.3
	2	803.9	3.2	92.6
2d "	2 3 4	811.8 817.3	3.0 3.3	88.4 87.0
	1	781.4	2.6	127.9
	2	792.0	3.5	124.4
3d "	1 2	796.0 792.7	4.1 2.0	126.5 124.9
	1	805.0	2.9	98.8
5th "	1			92.3

The residue of the serum contained on an average 7.0% of inorganic constituents.

In the first case, the first bleeding was ordered at the commencement of the disease, during the febrile period; the second at the commencement, and the third at about the middle of the eruptive stage. In the second case, the first bleeding was ordered some days before the appearance of the disease; the second during the fever; the third on the third day of the eruption, and the fourth on the sixteenth day of the eruption. In the third case, the first bleeding was ordered at the commencement of the eruption; the second during the suppurative stage. In the fourth case, both venesecti ons were prescribed during the height of the eruption. In the fifth case the pustules were filled with blood (variole hémorragique:) the bleeding was ordered when the eruption was at its height.

The analyses of blood in varioloid gave the following results:

Water.	Fibrin.	Blood-corpuscles.	Residue of serum.
785.6	2.3	120.3	91.8
782.1	2.4	125.6	89.7

The residue of the serum contained 7.6% of inorganic matter in the second analysis.

In the first instance the bleeding was performed on the 3d day; and in the second case on the 2d day of the eruption.

Rubeola. (*Morbilli.*)

Andral and Gavarret found that in the measles the fibrin never exceeded, nor did it ever fall much below Lecanu's average. In

most cases the corpuscles were above the normal standard. I quote the following analyses from their researches:

Venesection.	Day of eruption.	Water.	Fibrin.	Blood-corpuscles.	Residue of serum.
1st Case	1	760·2	26	146·6	90·6
" "	2	766·9	30	140·9	89·2
3d "	1	781·6	26	137·1	78·7
4th "	{ 1 2	786·7 795·8	25 27	137·5 131·6	73·4 70·1
5th "	{ 1 2	792·1 823·2	24 34	118·6 93·3	86·9 80·1

The residue of the serum contained on an average 8·4% of inorganic constituents, which was one of the highest amounts that occurred in the course of their researches.

The patient in case 3 had also been bled on the first day of the eruption: the second bleeding in case 4 was performed on the second day after the disappearance of the eruption.

The young woman from whom the blood in case 5 was taken, presented so strongly the general appearances of anaemia in consequence of excessive menstruation, that the amount of corpuscles, 118·6, may be regarded as very high: the second venesection was performed after the disappearance of the eruption, and when symptoms of tubercular phthisis were very apparent.

Scarlatica.

Andral and Gavarret have made four analyses of the blood of three persons suffering from scarlatina. Two of these analyses decidedly indicate the character of hypnosis, although not in a very marked degree. The two other cases present differences which will be presently explained:

Venesection.	Water.	Fibrin.	Blood-corpuscles.	Residue of serum.
1st Case { 1	761·5	3·1	146·0	89·4
2d " { 2	782·6	4·0	134·3	89·1
3d " { 1	776·3	3·5	136·1	84·1

The first bleeding in the first case was ordered on the second day of the eruption; the second during convalescence. At this period a number of boils had appeared, and there was considerable fever, to which two circumstances the change in the blood is attributable.

The bleeding in the second case was ordered on the second day of the eruption.

Lecanu¹ has also made two analyses of the blood in this disease, and has obtained nearly similar results.

	Blood of a man aged 35 years.	Blood of a man aged 18 years.
Water	- - - - 776·55	770·41
Blood-corpuscles	- - - 144·55	146·80
Residue of serum	- - - 78·90	82·79

The quantity of fibrin was not determined by Lecanu.

¹ Etudes Chimiques, etc., p. 97.

Febris intermittens.

From the analyses made by Andral and Gavarret of the blood in this disease, we are led to conclude that instead of being in a state of hypnosis, the blood exhibits rather a tendency towards hyper-nosis. Andral and Gavarret themselves remark, that in consequence of the absence of all disturbance in the normal functions of the organism during the remission of the febrile symptoms, it might be concluded *a priori* that no peculiar changes would be exhibited in the blood.

The fibrin rises a little above the normal average; the corpuscles, however, with the exception of one case in which the bleeding was ordered at the commencement of a second attack, fall below the normal proportion. The blood in most of these cases was, however, taken from persons suffering from long standing tertian or quotidian fever.

The period at which the blood was taken, whether during the remission, the hot or the cold stage, seemed to exert no influence on the composition of the fluid.

It will be sufficient to give the maxima, minima, and mean of their researches.

	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Residue of serum.
Maximum	847.9	221.9	3.6	127.9	91.0
Minimum	778.1	152.1	3.0	68.8	71.6
Mean of 7 analyses	811.4	188.6	3.3	104.3	80.0

The loss of a considerable quantity of blood by hemorrhage must necessarily influence the composition of the blood remaining in the system. This will be shown (as we have already seen in the Phlogoses) by the diminution of the corpuscles, and in most cases of the fibrin also.

From the blood taken from the body we can usually draw a pretty safe inference regarding the composition of the blood remaining in the system; a thick readily coagulating blood usually indicates an abundance of the circulating fluid, and especially a considerable quantity of corpuscles and fibrin, while a thin non-coagulating blood implies a deficiency of those two constituents.

The blood does not, however, exhibit the same changes of composition in all the diseases that are classed as hemorrhages. On the contrary, it has been shown by Andral and Gavarret that the composition of the blood in spontaneous cerebral hemorrhage is similar to that which is so characteristic in typhoid fever.

Hæmorrhagia cerebralis.

Andral and Gavarret found that the quantity of fibrin in the majority of cases of apoplexia cerebralis, and of the cerebral congestion known as the forerunner of that disease, was less than in healthy blood; the amount of corpuscles was, however, frequently absolutely increased, and, excepting in a few cases, was larger, in

proportion to the fibrin, than in the healthy fluid. These solid constituents were generally rather increased; circumstances which all correspond with a state of hypnosis.

These points are most strikingly seen in certain cases of spontaneous cerebral hemorrhage, when, for instance, in correspondence with the small amount 1·9 of fibrin no less than 175·5 of corpuscles were found.

Andral and Gavarret have made eight analyses of the blood of seven persons suffering from this affection. Their results are given in the following table;—

Venection.	Period from commencement of disease.	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Residue of serum.
1st Case	1	1	790·9	209·1	2·2	135·9
2d	{ 1	3	742·3	257·7	1·9	175·5
3d	{ 2	6	770·2	220·8	3·5	137·7
4th	1	3	770·8	229·2	2·6	140·6
5th	1	4	791·8	208·2	3·9	126·5
6th	1	8	806·9	193·1	2·0	120·8
7th	1	—	791·3	208·7	2·1	122·4
		5	774·0	226·0	3·2	123·4

The residue of the serum contained, on an average, 7·9% of inorganic constituents, which shows that the quantity of salts is not diminished.

The blood in the first case was taken from a woman aged 60 years, whose feet had been oedematous for six months, in consequence of hypertrophy of the heart.

The second case was that of a woman aged, 59 years, who, two days before the bleeding, had a severe apoplectic fit; the blood exhibited decided symptoms of hypnosis, the fibrin being diminished, and the corpuscles and (to a very considerable degree) the solid constituents being increased. The bleeding was repeated three days afterwards, when consciousness had returned, and at this period the corpuscles were found to have diminished in a very striking degree, being about 25% less than on the former occasion; the fibrin in the meantime increased in a still more rapid proportion.

Andral and Gavarret observe, in regard to this case, that the slight cerebral hemorrhage is not sufficient to account satisfactorily for the change in the composition of the blood that was observed on the second occasion; moreover, since the loss of blood is not always necessarily followed by a diminution of fibrin, it may be asked whether the changed composition of the blood, instead of being a consequence, may not have been a cause of the disease, since blood deficient in its proper quantity of fibrin has always a tendency to escape from the vessels.¹

The change in the composition of the blood is proportional to the

¹ In opposition to this view it may be stated that blood containing uninjured corpuscles cannot be effused unless there are orifices in the parietes of the vessels, and it is questionable whether blood abounding in fibrin can escape through such pores at all, while blood deficient in that constituent can pass through with facility. The only constituent that can permeate the walls of uninjured vessels is hemato-globulin dissolved in liquor sanguinis; and this solution is not produced by a diminution in the amount of fibrin, since the corpuscles are insoluble

violence of the attack, as is seen in the third case, where the fibrin is only slightly diminished, although the corpuscles are considerably increased.

Consciousness remained in the fourth and fifth cases. The increase of the fibrin, while the corpuscles remained stationary, is deserving of notice in the former of these cases. In the sixth case the hemorrhage had occurred three weeks before the venesection, and was followed by entire hemiplegia of the left side. In the seventh case the patient had previously been bled on the third day of the attack; she had retained her consciousness.

Andral and Gavarret have made 21 analyses of the blood of 15 persons suffering from cerebral congestion (the usual prodromus of spontaneous cerebral hemorrhage.) Its symptoms are intense headache, giddiness, and a tendency towards epistaxis.

In the majority of these cases the fibrin was found to be below the normal quantity. It twice rose to 3.7, once to 3.5, and once to 3.2; in all the other cases it was below the normal amount, and it occurred as low as 1.6.

The amount of blood-corpuscles was pretty near the standard average; in two instances it rose to 152 and 154; and in two other cases, (the one a woman of weakly condition, and the other a person under the noxious influence of lead,) it fell to 88.

I shall only give the maxima, minima, and mean of these researches:

	Water.	Solid constituents.	Fibrin.	Blood corpuscles.	Residue of serum.
Maximum -	890.3	259.8	3.7	152.3	104.8
Minimum -	740.2	179.7	1.6	88.3	76.4
Mean -	787.1	212.9	2.6	120.0	89.7
Healthy blood -	790.0	210.0	3.0	127.0	80.0

The residue of the serum contained, on an average, 7.9% of inorganic constituents, the same amount as in cerebral hemorrhage.

No causes can be assigned with any degree of certainty to the peculiar modification of the blood to which I have assigned the term *hypnosis*.

The composition of the blood in hypnosis is essentially the reverse of that in hyperinosis. The amount of corpuscles is increased, that of fibrin diminished, and the solid constituents generally are increased rather than diminished; while in the phlogoses they are most commonly below the normal standard. We have seen in the previous analyses that in proportion as the febrile symptoms assumed the form of erethismus, the characters of hypnosis became less marked; and, on the other hand, that when they took on a torpid type these characters were more strikingly developed.

in desublimated serum, provided a sufficient amount of chloride of sodium be contained in it. On the other hand, the solubility of the hemato-globulin in the liquor sanguinis and its consequent property of escaping through the walls of the vessels may arise from an absolute decrease of salts or from an increased amount of water in the blood. In the analyses quoted in the text the salts were not diminished.

If we assume that the circulation of the blood is accelerated in inflammatory fever, we may regard it as impeded in torpid fever. In the one case, the blood abounding in fibrin acts as an increased stimulus to the heart; in the other, the heart partially loses its power of action. Its contractions succeed each other, it is true, with increased rapidity, but the blood-wave, propelled at each systole, is diminished and powerless, and the pulse, although much quickened, is small and wiry.

In consequence of the delay thus occasioned in the motion of the general mass of the blood, oxygen cannot act so efficiently on it as in the normal state of the circulation, and consequently the blood does not possess the bright red colour observed in inflammatory affections, but is dark, and the temperature, instead of being increased, is often diminished, as has been observed by Schönlein, in typhus. Hence the metamorphosis of the blood, instead of being accelerated, as in hypernoia, is impeded, and consequently the ratio of the corpuscles to the albumen is reversed. In abdominal typhus, the amount of the corpuscles is rendered more striking, by the diminution of albumen, which constituent is removed from the blood by the profuse diarrhoea that accompanies this disease.

From these observations it is very probable that the primary cause of this modification of the blood may, in a great measure, be referred to the impeded circulation, and to the deficient energy of the heart's action, which may be regarded as indications of the depressed vitality of the blood itself; but at the same time the influence of the nerves on its composition and on the circulation (although how they act we know not) must not be overlooked.

Finally, it must be observed that the state of hypnosis is not a permanent one; it lasts only for a brief period, till the blood either begins to exhibit more vital activity, and to return towards its normal condition; or, if its vitality be still more depressed, till it assumes the character of spanæmia. The preponderance of the corpuscles is not absolute (as in plethora,¹) but merely relative, and is due, partly to their hindered consumption, and partly (as is seen in abdominal typhus) to an absolute diminution of the water and the albumen. If the fever assume a malignant torpid character, the hypnosis speedily merges into spanæmia.

THIRD FORM OF DISEASED BLOOD : SPANÆMIA.²

The chemical and physical relations of the blood in those states in which it is deficient in solid constituents, and especially in fibrin and blood-corpuscles, are not yet accurately known.

We have less frequent opportunities of examining this condition

¹ [Becquerel and Rodier have recently shown that this opinion is erroneous, and that, in plethora, the amount of the blood is increased, while its composition is unaffected.]

² From *αιμα*, blood, and *στρας*, or *στρανεια*, poor; spanæmia, poverty of the blood. We prefer this term to anæmia, because the latter is used to represent a morbid condition of the blood subordinate to spanæmia.

of the blood, for some of the diseases in which it occurs are of rare occurrence, and in the other more common forms, the prudent physician avoids as much as possible increasing by venesection the general want of blood in the system.

Chemical characters of the blood.

The amount of fibrin and of corpuscles is diminished: the amount of residue of serum is either normal or diminished: the proportion of water is higher than in healthy blood: the amount of salts in the serum is sometimes normal, sometimes diminished.

Physical characters of the blood.

The blood is very fluid; it is sometimes of a dark or even violet, and sometimes of a bright colour; it usually coagulates imperfectly, sometimes not at all. The clot is small, soft, diffluent, and neither covered with a true nor false buffy coat. The serum is generally of a bright yellow colour, but sometimes of a dark yellow or even red tint. The specific gravity of the blood is considerably diminished.

This form of diseased blood appears capable of being subdivided into two classes: one embracing diseases primarily dependent upon the chylopoietic viscera, such as are due to bad food, deficient and improper formation of chyle, atmospheric influences, protracted action of poisonous mineral agents (lead, mercury and its compounds, chlorine, iodine, &c.); and finally to inordinate consumption of the blood through a deficiency of the animal fluids.

The corpuscles, which, as we have seen, are of the utmost importance in the blood, are either not produced in sufficient quantity, or are consumed in a quicker proportion than they are reproduced. The liquor sanguinis, although poor in fibrin, may yet contain a sufficient quantity of albumen and salts to prevent the relatively increased quantity of water from dissolving the corpuscles.

All the diseases arranged by Schönlein under the family *cyanoses* belong to this subdivision.

The other subdivision embraces certain diseases characterized by the peculiar composition of the blood, but in which the primary causes of its change of composition are quite distinct from those which act in the *cyanoses*, and are probably dependent upon the central nervous system. A peculiar state of the atmosphere (most likely due to certain changes in its chemical composition,) protracted wars, the effluvia of decaying animal matter, &c., are assigned as the external causes of the production of these disorders, the principal of which are abdominal typhus, petechial typhus, the yellow fever, and the plague.

In the *cyanoses*, as also in the malignant (putrid) form of typhus, passive hemorrhages are by no means rare.

It has been asserted that the deficiency of fibrin and of corpuscles

renders the blood liable to exude through the walls of the vessels. It is clear, however, that the colouring matter cannot escape through the walls of the capillaries, unless such a change occurs as to render the hæmato-globulin soluble in the liquor sanguinis, since perfect corpuscles are not capable of passing through the uninjured walls of the vascular system. As the blood which is discharged by the epistaxis in the *morbus maculosus Werlhofii* (as well as menstrual blood) contains corpuscles, the walls of the vessels must be imperfectly closed. Such a form of blood appears to occur in the putrid form of abdominal or petechial typhus. The hæmato-globulin becomes soluble in the liquor sanguinis, in consequence of a deficiency in the due proportion of salts, and an excess of water; in this case we may therefore speak of a red, bloody transudation.

L. CYANOSIS.

Anæmia and hydræmia.

The blood in anæmia is essentially different from the normal composition. If the anæmia has arisen from excessive loss of blood, we may fairly assume that the total mass of that fluid has diminished. This, in fact, constitutes true anæmia. The composition is, however, also changed; it is poor in corpuscles and in fibrin, because these constituents are not so easily supplied as the albumen, which may be obtained at once from the lymphatics. The quantity of the solid constituents is also found to be diminished, if the quantity of the corpuscles is (either absolutely or relatively) decreased: the quantity of water is, therefore, increased, which induces the state of the blood known as hydræmia. Anæmia and hydræmia cannot be well separated, as a decrease in the solid constituents is usually produced by every loss of blood.

If the anæmia is caused by abnormal or deficient chylification, the proper quantity of liquor sanguinis may be present, while the corpuscles and fibrin are diminished: in this case, also, the absolute quantity of solid constituents is lessened.

The decrease of the solid constituents will probably attain its maximum under the combined influences of an unhealthy humid atmosphere, and improper, unsuitable nourishment. Under these circumstances the blood will resemble a viscid light-coloured watery fluid.

I have not analyzed the blood in any cases of anæmia, but, it is usually described as clear, watery, and viscid. The clot, if it forms at all, is small, soft, and diffuent; the fibrin, after it has been separated by whipping, is not tough and firm, but soft and viscid, and in the same state as it occurs in the chyle. The serum is slightly coloured and transparent. It has not been accurately ascertained whether the salts are decreased or in a normal proportion.

In hydræmia, the serum (as has been observed by Aneell,¹) is

¹ Course of Lectures on the Blood. The Lancet, 1840, p. 667.

usually transparent, and contains only a small quantity of colouring matter, and probably only a slight amount of salts.¹ Geddings² observes regarding the inhabitants of the morasses of the Carolinas, in whom anaemia, or, more correctly speaking, hydræmia, is developed in a high degree, that the temperature of the body is reduced, that the respiration is short and laborious, and that the pulse is small, tremulous, and frequent. In the examination of the heart and larger vessels of anaemic persons he found either scarcely any coagulated blood, or else a clear red, or greenish dirty-looking fluid, almost entirely devoid of solid or colouring constituents, containing but few blood-corpuscles, and which could not be coagulated either by heat or by nitric acid. This watery fluid was frequently present in considerable quantity.

Carcinoma.

In a case of cancer of the left lobe of the liver, and of the pylorus, accompanied with atrophy of the spleen, occurring in a man, aged 53 years, the blood contained:

Analysis 31.			
Water	-	-	887·2
Solid constituents	-	-	112·8
Fibrin	-	-	3·0
Albumen	-	-	55·1
Blood-corpuscles	-	-	45·8
Extractive matters and salts	-	-	8·9

Scrofulosis.

In scrofulous affections the blood is deficient in solid constituents, especially in fibrin and in corpuscles. The primary causes are probably due to a deficient formation of chyle, and to the influence of a moist unhealthy atmosphere.

Dubois³ has analyzed the blood of scrofulous persons. The blood coagulates slowly, the clot is small, soft, and diffuent; the serum is thin, and often of a red colour. When examined under the microscope, some of the corpuscles appeared devoid of colour at the edges only, some entirely colourless. Their size was not materially changed, but they appeared flattened, spherical, or cylindrical. Hence we may also infer that there is a deficiency in the quantity of salts in the blood of scrofulous persons.

Chlorosis.

The blood in this disease possesses the general characters of this fluid in anaemia. The clot is small, sometimes soft, but frequently of the normal consistence: the serum is bright, slightly coloured, and tolerably clear. The fibrin (separated by whipping) is not so dense and

¹ The blood-corpuscles would, however, be dissolved in this case.

² Baltimore Med. and Surg. Journal, 1834, No. 4.

³ L'Expérience, 1839, No. 57.

consistent as in normal or in inflammatory blood. Its quantity is normal, or only slightly diminished, while the amount of the corpuscles is considerably decreased, and the solid constituents generally are less than in healthy blood.

Golding Bird¹ states, however, that the blood in chlorosis forms just as solid a clot as in inflammatory diseases, and Jennings² observed even a buffy coat on the clot of chlorotic persons in the absence of all inflammatory symptoms. He accounts for this phenomena by supposing that as, in chlorosis, the amount of fibrin is normal, but that of the corpuscles much diminished, the ratio of the fibrin to the corpuscles may be the same as in inflammatory disorders.

Andral and Gavarret state that the blood in chlorotic persons forms a clot similar to the coagulum in healthy blood, and that a buffy coat is not unfrequently observed on it.

I found, on the contrary, that the clot in chlorosis was very soft, and that the fibrin was not so firm as in inflammatory diseases. These contradictions are easily explained by supposing that the chemico-physical characters of the blood change during the progressive development of the disease. We can obtain a more accurate knowledge of the stage of development of the disease from the blood than from many other diagnostic signs.

I am indebted to Dr. Vetter for the following specimen of the blood of a chlorotic girl, which gave, on analysis, the following results:

		Analysis 32.	Healthy blood.
Water	- - - -	871-500	795-275
Solid constituents	- - - -	128-500	204-022
Fibrin	- - - -	2-080	2-104
Fat	- - - -	2-530	2-346
Albumen	- - - -	79-220	76-660
Globulin	- - - -	30-660	103-022
Hæmatin	- - - -	1-431	6-209
Extractive matters and salts	- - - -	11-000	12-012

The hæmato-globulin contained 4-4% of colouring matter.

The girl was 19 years of age, moving in a respectable station, and tall; she exhibited all the symptoms of unmixed, long-standing chlorosis, which appeared in this instance to have reached its highest development.

On contrasting it with healthy blood, we find little difference in the absolute quantity of fibrin; this constituent is, however, extremely large when considered relatively with the corpuscles, or with the solid constituents generally.

The quantities of albumen and of extractive matters and salts do not differ very much from the quantities of healthy blood.

Andral and Gavarret have analyzed the blood in several cases of this disease. It is different in the incipient and in the fully-developed stages of chlorosis.

In the former the appearance of the patient hardly indicates the pre-

¹ Ancell, Course of Lectures, &c. The Lancet, 1840, p. 887.

² Ibid.

sence of the disease; the face is blooming, rather than pale, and the blood merely exhibits a very considerable decrease of the corpuscles.

The following numbers give the maxima, minima, and mean of 8 analyses, made during this stage.

	Water.	Solid constituents.	Fibrin.	Blood-corpuscles.	Solid residue of serum.
Maximum - - -	816·3	210·0	5·3	112·7	94·1
Minimum - - -	790·0	183·7	2·4	97·7	76·5
Mean - - -	801·0	199·0	3·5	106·8	88·0
Healthy blood, according to Lecanu -	790·0	210·0	3·0	127·0	80·0

When the disease is fully developed the fibrin is slightly diminished, but the quantities of blood-corpuscles, and of the solid residue generally are very much lessened.

Andral and Gavarret have made 12 analyses of the blood of 9 cases of confirmed chlorosis.

I shall give the maxima, minima, and mean results of these analyses; omitting, however, the cases that were complicated with inflammatory symptoms.

	Water.	Solid residue.	Fibrin.	Blood-corpuscles.	Residue of serum.
Maximum - - -	868·7	181·3	3·6	95·7	100·9
Minimum - - -	818·5	131·5	2·1	35·7	75·4
Mean - - -	853·2	146·8	2·9	56·7	88·0

The blood in which the corpuscles attained their minimum, had the following composition:

Water - - -	-	-	-	-	868·7
Solid constituents - - -	-	-	-	-	131·3
Fibrin - - -	-	-	-	-	3·5
Blood-corpuscles - - -	-	-	-	-	35·7
Solid residue of serum - - -	-	-	-	-	88·0

The amount of corpuscles exceeds, in only three cases, the number 60: and in five cases it remains below 50: the fibrin remains in five cases below 3, and in the other five cases it amounts to or exceeds 3, the maximum being 3·6. The amount of the solid residue of the serum is in almost every case rather above the normal standard. It follows from 4 analyses, in two of which, however, the chlorosis was combined with tubercular phthisis and rheumatism, that the residue of the serum contains on an average 8·2 of inorganic constituents.—The two cases of pure chlorosis gave the inorganic constituents of the residue of the serum at 8·9, while the two complicated cases gave only 7·6, so that it appears as if the salts were rather increased than diminished in this disease. Others, however, assert that there is a diminution of the salts.

[The following table gives the mean composition of the blood of six chlorotic girls, as determined by Becquerel and Rodier:

Density of defibrinated blood	-	1045·8
Density of serum	-	1028·1
Water	-	828·2
Solid constituents	-	171·8
Fibrin	-	34

Fat	-	-	-	-	-	1·5
Albumen	-	-	-	-	-	72·1
Blood-corpuscles	-	-	-	-	-	86·0
Extractive matters and salts	-	-	-	-	-	8·8

The salts consisted of:

Chloride of sodium	-	-	-	3·1
Other soluble salts	-	-	-	2·3
Phosphates	-	-	-	0·441
Iron	-	-	-	0·319]

My own observations, as well as those of Andral and Gavarret, on the blood of chlorotic persons who had been taking ferruginous medicines, are especially interesting.

The girl from whom the blood of analysis 32 was taken, took 2 ounces of the tincture of iron and 64 grains of metallic iron, during a period of seven weeks, commencing with the day of the first venesection.

The blood which was then analyzed had the following constitution:

Analysis 33.

Water	-	-	-	806·500
Solid residue	-	-	-	193·500
Fibrin	-	-	-	1·200
Fat	-	-	-	2·299
Albumen	-	-	-	81·230
Globulin	-	-	-	90·810
Hæmatin	-	-	-	4·598
Extractive matters and salts	-	-	-	9·580

The hæmato-globulin contained 4·8% of colouring matter.

This change in the composition of the blood is truly surprising, and affords an excellent illustration of the wonderful effects of certain remedies. The amount of solid constituents is increased by nearly one half, and the increase of the hæmato-globulin is likewise extraordinary. In this, as well as in Andral and Gavarret's observations, the quantity of the fibrin is diminished: the proportion of the hæmatin to the globulin is however slightly, although not materially, increased.

The changes in the condition of the patient kept pace with those of the blood. Before, she was pale, and her lips colourless; now she presented a really blooming appearance. Andral and Gavarret have arrived at perfectly analogous results.

They give two cases, in one of which the iron was administered for four weeks, in the other for only three weeks.

1st Case.

	Previous to use of the iron.	After use of the iron.
Water	-	866·5
Fibrin	-	30
Blood-corpuscles	-	46·4
Residue of serum	-	83·9

2d Case.

Water	-	852·8	831·5
Fibrin	-	35	3·3
Blood-corpuscles	-	49·7	64·3
Residue of serum	-	94·0	100·9

[The two following analyses were made by Herberger.¹ The blood in (1) was taken from a chlorotic girl aged 20 years; in (2) it was taken from the same girl after an eight weeks' course of chalybeates.

In both instances the blood formed a tolerably large clot, but no buffy coat.

	1.	2.
Water	868·340	807·080
Solid constituents	131·660	192·920
Fibrin	3·609	1·950
Fat	2·310	2·470
Albumen	78·200	81·509
Globulin	36·470	94·290
Hæmatin	1·590	4·029
Extractive matters and salts	8·941	8·236]

Andral and Gavarret have likewise analyzed the blood of a chlorotic man. They made three analyses of it at intervals of four weeks each. During this time he had been taking iron, but without any marked advantage:

Venection.	Water.	Fibrin.	Blood-corpuscles.	Residue of serum.
1	810·1	3·6	87·9	98·4
2	831·5	3·4	77·2	87·9
3	819·4	3·7	86·9	90·0

The blood of chlorotic persons has also been analyzed by Lecanu² and Jennings.³ The following are the results of their analyses.

	Lecanu.		Jennings.	
	1.	2.	1.	2.
Water	862·40	861·97	871·0	852·0
Fibrin	-	-	5·0	3·0
Blood-corpuscles	55·15	51·29	48·7	52·0
Residue of serum	82·45	86·74		
Albumen	-	-	60·0	78·0
Fat	-	-	1·7	2·0
Extractive matters	-	-	3·0	2·0
Alkaline salts	-	-	7·6	7·0
Earthy salts	-	-	1·8	2·0

Andral and Gavarret consider that the great rarity of cases of hemorrhage in chlorotic persons is due to the amount of fibrin remaining normal, while the blood-corpuscles are considerably diminished. I cannot, however, think that the primary cause of ordinary hemorrhage is only to be sought for in the peculiarities of the blood. That a lesion of the vessels occurs in the majority of cases of hemorrhage is obvious from the circumstance of blood-corpuscles being found in the effused fluid. I cannot easily conceive how blood, deficient in fibrin, should more readily escape from the vessels than blood abounding in that constituent.

In passive hemorrhages, the relations of the tissues themselves ought to be taken into account as much as the quality of the blood.

[Becquerel and Rodier analyzed the blood of two girls, in whom all the symptoms of chlorosis existed, (including the *bruit de diable*

¹ Buchner's Repertorium, 2d series, vol. 29

² Etudes Chimiques, etc., p. 113.

³ The Lancet, 1839-40, p. 867.

in the carotids,) and yet there was no diminution of the corpuscles, or of the solid constituents generally.

		1st Case.	2d Case.
Density of defibrinated blood	- - -	1055·4	1055·4
Density of serum	- - -	1027·9	1027·2
Water	- - -	798·6	792·7
Solid constituents	- - -	201·4	207·3
Fibrin	- - -	29	23
Fat	- - -	1·267	1·980
Albumen	- - -	66·8	70·5
Blood-corpuscles	- - -	123·8	126·4
Extractive matters and salts	- -	6·6	5·8

The salts consisted of,

Chloride of sodium	- - -	2·6	3·0
Other soluble salts	- - -	2·2	3·4
Phosphates	- - -	0·329	0·427
Iron	- - -	0·492	0·516]

Scorbutus.

[The blood has been analyzed by Mr. Busk in three well-marked cases of scurvy that occurred in the Dreadnought Hospital Ship. Its composition is represented in the following table:

	1.	2.	3.	4. Healthy blood. (Busk.)
Water	- - -	849·9	835·9	846·2 788·8
Solid constituents	150·1	164·1	153·8	211·2
Fibrin	- -	6·5	4·5	5·9 3·3
Albumen	- -	84·0	76·6	74·2 67·2
Blood-corpuscles	- -	47·8	72·3	60·7 133·7
Salts	- -	9·5	11·5	10·9 6·8

These analyses are sufficient to disprove the general notion that in this disease the corpuscles are dissolved in the serum. In the blood taken from these scorbutic patients, the separation into serum and clot was as perfect and took place as rapidly as in healthy blood. In two of the cases the clot was buffed and cupped.]

Morbus maculosus Werlhofii.

[*Porphyra haemorrhagica* (Mason Good.) Land-scurvy.]

I have analyzed the sanguineous fluid discharged from the mouth of a girl aged 20 years. She was pale and weak, the pulse rather excited, breath fetid, and there were red spots on the gums and above the uvula, from which the blood had apparently escaped. This sanguineous fluid contained much saliva, and some flocculi of mucus, but no fibrin. It had a faint, disagreeable smell, was of a very dark (almost black) red colour, transparent, and deposited an almost clear sediment. The decanted fluid exhibited no blood-corpuscles under the microscope, and only a few membranous granules. The sediment was composed of blood-corpuscles, which, for the most part, were changed from the flattened into a spherical form, and of which a small quantity were of a pale yellow colour, while the majority were almost,

if not quite, colourless. Moreover, I observed a considerable quantity of epithelium-scales and mucus-granules, the latter of which were especially visible in the flocculi deposited at the bottom. After thoroughly stirring the fluid, it was boiled; upon which it coagulated perfectly. I found that it was composed of—

	Analysis 34.
Water	948.889
Solid residue	51.111
Fat	1.377
Albumen and mucus	34.032
Globulin	5.610
Hæmatin	0.102
Alcohol-extract, bilin, and salts	4.685
Water-extract, ptyalin, and salts	2.555
Biliverdin	0.366

The presence of the bile in this blood, although I was assured, both by the patient and the nurse, that there had been no vomiting when the blood was discharged, appeared to me of importance, since it is well known that a very small quantity of bile is sufficient to dissolve a considerable quantity of blood-corpuscles.

[Some observations on the sanguineous contents of the stomach, and on the blood found in the heart after death from this disease, occur in Heller's Archiv. vol. i. p. 10.]

Hemorrhages.

I have already observed that continuous and excessive loss of blood must necessarily produce a change in the composition of that portion which remains in the system, and that there will be a more or less marked degree of spanæmia in proportion to the quantity of blood that has been lost.

Some researches have already been made regarding the chemico-physical condition of the blood which is separated from various organs in the different forms of hemorrhage.

I analyzed the blood of a woman who was suffering from melæna. It was a thick fluid, of a dark red colour (nearly black), and gave off only a slight fæcal odour: dilute acid heightened the colour, and caustic potash developed an odour of ammonia: it had a strong alkaline reaction, coagulated only imperfectly on heating, and threw out an unpleasant smell, not however resembling the odour of fæces. It did not coagulate upon standing, and contained no fibrin. No blood-corpuscles could be observed under the microscope, but merely some yellow particles floating in a clear fluid. It was very rich in fat and in hæmaphæin. The fat resembled in odour the fat of putrid blood. The alcohol-extract, which contained a considerable quantity of fat, had a very bitter taste, but when treated with sulphuric acid no bilifellinic acid was separated; consequently the presence of bile was undecided. Upon heating the dried residue a considerable quantity of ammonia was given off.

The blood contained in 1000 parts:

	Analysis 35.
Water	886-200
Solid residue	113-800
Brown fat	9-000
Albumen	39-830
Globulin	36-530
Hæmatin	3-018
Hæmaphæin	2-280
Hæmaphæin with alcohol-extract, and salts	9-673
Water-extract and salts	10-355

The hæmaphæin left upon incineration a trace of peroxide of iron, and some carbonate of soda; the alcohol-extract left chloride of sodium and carbonate of soda; and the water-extract left chloride of sodium, carbonate of soda, sulphate of soda, and phosphate of lime.

The blood discharged in hæmatemesis is, according to Schönlein's observations, either clear and very fluid, or black and coagulated; sometimes the two forms are mixed. The taste of the blood is bitter if any bile is mixed with it, acid if the spleen is affected.

Ancell¹ states that vomited blood is often coagulated, of a dark brown or blackish colour (in consequence of the acids of the stomach); in other cases it resembles coffee-grounds.

In a girl, who brought up enormous quantities of blood, I found that it occurred, for the most part, in rather large brownish red coagula: the fluid had a faintly acid reaction, but on touching a section of a clot with red litmus paper, a blue tint was produced. The microscope revealed the presence of corpuscles in a state of good preservation.

In haematuria the blood is mixed with urine. If the quantity of the blood is very small, all the blood-corpuscles may become dissolved, as I have frequently observed. The urine, however, coagulates on heating, and the colour disappears after boiling, while discoloured flocculi are thrown down. The corpuscles are frequently preserved entire, and form a sediment, on allowing the urine to stand for some time. In this case they can be detected by the microscope.

Lecanu² quotes an opinion of Delarive, that a change occurs in the colouring matter of the blood that escapes in haematuria, since sulphuric acid produces a brown-red instead of a black-red, and nitric and muriatic acids produce a white instead of a black-red precipitate: alcohol also produces a white deposit. These peculiarities in colour (especially the white precipitate) may probably be explained by the precipitation of the albumen, while in consequence of the dilution of the blood the hæmato-globulin escapes precipitation.

Purpura hæmorrhagica.

[The blood has been analyzed in a case of this disease by Routier.³ In 1000 parts he found:

¹ *The Lancet*, Sept. 1840, p. 842.

² *Etudes Chimiques, etc.*, p. 95.

³ *Gazette des Hopitaux*, vol. 6, No. 90.

Water - - - - -	795.244
Solid constituents - - - - -	204.756
Fibrin - - - - -	0.905
Blood-corpuscles - - - - -	121.701
Residue of serum - - - - -	83.405

From this analysis it appears that the blood does not assume the form of spanæmia. It is placed here in consequence of the analogy between purpura hemorrhagica and the preceding diseases.]

Typhus petechialis putridus. Yellow fever. Plague.

The blood in these diseases is described as watery, very poor in fibrin, and of a dark colour. If any clot be formed, it is diffluent, and very soft: the serum is frequently of a deep yellow or brown-red colour, partly from the colouring matter of the bile, and partly from dissolved hæmato-globulin. It possesses a very peculiar smell, which probably differs in each disease. It is by no means improbable that this smell may be produced by a volatile salt of ammonia.

Schönlein has directed attention to the formation of a peculiar gas that escapes with the blood in the post-mortem examination, on opening the large vascular trunks, and which is probably developed in the blood during the last stage of the disease.

Chomel also speaks of the development of a gas in the interior of the veins.

Ancell¹ remarks, that in the first stage of the endemic yellow fever of the West Indies the blood is of a brighter red, contains more salts, and is hotter than in a state of health. As the disease progresses, its characters become changed, and towards the termination of the malady it loses its saline and animal principles, and becomes black and thin; in which state sanguineous effusions occur from the different outlets and tissues.

Balard and Rochet² have made some observations on the properties of the blood in the plague.

Balard is of opinion that the lymphatic system is first disordered, and that inflammation, degeneration, and suppuration of the lymphatic ganglia, and vessels follow. It is not until suppuration in these structures has fairly set in that the venous system begins to suffer, and a change in the composition of the blood to ensue.

The blood, when the disease is fully established, exhibits invariably the same properties, whether it is obtained by bleeding, or taken from the vessels after death. The arterial and venous blood have both the same dark colour; the blood generally appears in a peculiar state of solution, and oily drops are frequently seen on its surface. It frequently has a peculiar smell, but never the buffy coat.

In three patients, aged 19, 23, and 27 years respectively, and in whom the blood was drawn between the third and fifth days, it was

¹ Course of Lectures on the Physiology and Pathology of the Blood. The Lancet, 1840, p. 837.

² Casper's Wochenschrift, 1838, No. 12.

of a dark-brown colour, and in the course of two hours a good clot was formed. This, however, is frequently not the case, especially when the oily globules appear. The serum was reddish, and developed a gas which soon browned sugar of lead test-paper, and which therefore contained sulphuretted hydrogen. The clot constituted about 40% and contained 33.5 of water, .6 of fibrin, 3.8 of crux, .25 of osmazome, .9 of chlorides of sodium and potassium, and .2 of carbonate of soda and fat.

Lachèze,¹ who observed the plague in Egypt, states that the blood never coagulates, that it is greasy, and of a black colour.

THE FOURTH FORM OF DISEASED BLOOD: HETEROCHYMEUSIS.²

I arrange under this form all those states of the blood in which a substance is present that does not exist in the normal fluid: when, for instance, the blood contains urea (in appreciable quantity,) sugar, colouring matter of the bile, fat, pus. The circumstances that lead to the establishment of this diseased condition of the blood are far less natural than those which are connected with the production of the three former classes. The arrangement is artificial, and merely adopted for convenience, since this class of diseases has simply this property in common, that the composition of the blood is here *qualitatively* changed, whilst in the three former it was only altered *quantitatively*. The putrid form of typhus, the yellow fever, and the plague, certainly might have been placed in this class, since colouring matter of the bile, and a salt of ammonia, are often found in the serum. I have, however, thought it best to place these diseases in the third class, because, in the first place, the presence of the abnormal constituents is not constant; and because, secondly, in consequence of the deficiency in the solid constituents of the blood in these disorders, they naturally occur under the class *spanæmia*.

I. BLOOD CONTAINING UREA: URÆMIA.

a. *Morbus Brightii.*

Andral and Gavarret describe the blood in this disease as characterized by a deficiency of albumen in the serum.

It is evident, however, both from my own and from Christison's researches, that the decrease of the solid constituents of the serum is not always the leading character in this disease. I have thought it right, therefore, to arrange this disease, on account of the nearly constant presence of urea in the blood, under the form heterochymeusis.

Christison,³ who has attentively studied the blood in this disease, describes it in the following manner: The blood in the first stage of the disease coagulates with a thick, firm, and cupped *buffy coat*.

¹ Magendie, *Leçons sur le Sang.* Bruxelles, 1839, p. 200.

² From *τρέπει* and *χυμός.*

³ On the Granular Degeneration of the Kidneys, etc., by R. Christison. Edin. 1839.

The serum is usually rather turbid, and when shaken with ether yields a small quantity of solid fat. The decrease in the density of the serum at this stage is very remarkable. While in healthy blood it is estimated at 1029—1031, it now sinks to 1020, or even 1019; and in connexion with this circumstance we find a large quantity of albumen in the urine.

Another very remarkable peculiarity is the presence of a certain quantity of urea in the serum.

The following changes occur in the progress of the disease: (1.) There is an excess of serum, the clot often constituting not more than one fourth of the blood. (2.) The density of the serum returns to its normal state, or even exceeds it; sometimes, however, it remains low, even in the advanced stages. (3.) The urea disappears as the disease advances, but usually reappears, towards the termination of the case, in even a larger amount than previously. (4.) The fibrin, which is increased in the first stage, returns to its normal amount as the disease advances, and only becomes considerable again during inflammatory complication. (5.) The most remarkable character of the blood in the advanced stage is the great decrease of blood-corpuscles, which frequently amount to only one third of the normal proportion.

I have analyzed the blood in four cases of Bright's disease, and obtained the following results:

	Analysis 36.	Analysis 37.	Analysis 38.	Analysis 39.
Water	830-690	836-691	823-461	839-700
Solid constituents	169-420	173-109	176-539	160-300
Fibrin	7-046	9-060	5-000	3-500
Fat	2-403	1-660	2-520	2-680
Albumen	103-694	109-432	97-010	63-400
Globulin	40-151	41-300	54-090	71-300
Hematin	3-608	4-377	5-100	4-910
Extractive matters and salts	12-348	13-290	12-819	11-380

The blood in analysis 36 was taken from a man aged 40, who had been treated for some time in our hospital for this disease: traces of urea were detected in the extractive matters, by the method given in page 160.—The blood in analysis 37 was taken from a man aged 20, whose feet and arms were so œdematosus as to render venesection a matter of some difficulty. Considerable quantities of urea were found in the blood.—The blood in analysis 38 was taken from a man aged 30, in whom the disease was not so advanced as in the former cases. A considerable quantity of urea was found in the serum, which exhibited a remarkable milk-white turbidity, not caused by fat in a state of suspension, but (as shown by the microscope) produced by numerous minute solid granules, which, by diluting the serum, and then allowing it to rest, were collected, washed, and analyzed. They were not soluble in alcohol or in ether, but dissolved after a continuous digestion in dilute acetic acid, from which they were precipitated by ferrocyanide of potassium. Hence I concluded that they were fibrin.

The blood in analysis 39 was taken from a man 36 years of age, at the commencement of the disease. Hæmaturia had occurred a few days previous to the venesection. The quantity of urea in this blood was very considerable.—The urine was albuminous in all these cases, especially in the last two.

It is worthy of remark that I have found the hæmato-globulin more abundant in hæmatin in these than in ordinary cases. It varied from 8 $\frac{1}{2}$ to 9 $\frac{1}{2}$.

Christison gives the following results of analyses of blood in Bright's disease:

	Water.	Solid constituents.	Fibrin.	Blood-corpuscles.	Residue of serum.
1	863.8	136.2	2.8	57.4	76.0
2	844.1	155.9	4.4	57.7	93.6
3	808.3	191.7	3.0	133.9	54.6
4	831.0	169.0	2.8	111.1	55.1
5	836.3	163.7	2.7	104.6	56.4
6	825.2	174.8	4.3	95.5	75.0
7	859.2	140.8	8.2	75.5	57.2
8	825.3	114.7	6.2	56.4	52.1
9	862.8	137.2	3.2	72.1	61.9
10	855.5	144.5	4.5	42.7	97.3
11	862.6	137.4	8.5	72.8	56.1
12	867.0	113.0	5.6	49.1	58.3
13	841.6	158.4	3.4	91.6	63.4

Christison's average composition of healthy blood being:

775.7	224.3	3.8	137.1	83.4
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The blood in the 3d analysis was taken from a robust man, aged 55 years, in the first stage of granular degeneration, and suffering from anasarca. The urine was very albuminous, but not bloody: the serum was milky, and abounded in urea.

The blood in the 5th analysis was taken from a man aged 48, suffering from anasarca and continued fever. The kidneys were in the first stage of granular degeneration; the urine contained a considerable quantity of albumen.—In the 6th case, the disease had reached the middle stage: the patient was at the same time suffering from anasarca and chronic catarrh: the blood contained urea.—In the 7th case, the disease was in the first stage; the patient (a man aged 42) was also suffering from peripneumonia and anasarca: the blood contained urea, and the urine was albuminous.

8th analysis. Blood of a youth aged 16 years, suffering from dropsy; kidneys in the middle stage of granular degeneration. The serum was peculiarly rich in solid constituents, and contained a considerable quantity of urea.

9th analysis. Blood of a man aged 23. The granular degeneration was more advanced, the blood contained urea.

10th analysis. Blood of a man aged 23, after having recovered from scarlatina. The disease in the kidneys was in an advanced stage: the blood was remarkable for the small quantity of corpuscles.

11th analysis. Blood of a woman aged 25 years, suffering from anasarca, catarrh, and chronic rheumatism. The degeneration of the

kidneys was in a very advanced stage. The blood contained urea, and the urine was albuminous.

12th analysis. Blood of a man aged 32, suffering from pleuritis and anasarca; kidneys in an advanced stage of the disease. Blood remarkable for the small quantity of corpuscles, and for the large amount of urea.

13th analysis. Blood of a woman aged 56, with anasarca and ascites; the disease of the kidneys was in a very advanced stage.

These observations entirely coincide with my own, as far as regards the decreased quantity of solid constituents, the small amount of blood-corpuscles, as the disease advances, and the presence of urea in the blood.

Andral and Gavarret have analyzed the blood of three persons with Bright's disease.

The following are their results:

Venesection.	Water.	Solid constituents.	Fibrin.	Blood-corpuscles.	Residue of serum.
1st Case 1	801·0	199·0	1·6	127·6	69·1
2d " 1	867·0	133·0	2·3	61·6	69·4
3d " { 1	849·0	151·0	3·2	82·4	64·8
3d " { 2	836·0	164·0	3·0	88·2	73·7
3d " { 3	845·9	154·1	4·2	71·0	78·9

The second venesection in the 3d case was ordered at a time when the urine was less albuminous than it had been: the third was prescribed after a considerable interval, and when the urine contained no albumen.

β. Cholera.

The researches of trustworthy observers have shown that the blood in cholera exhibits the following peculiarities. The quantity of water is decreased, and consequently there is an increase in the amount of solid constituents arising, in all probability, from the watery alvine evacuations; the amount of fibrin, as well as the alkaline reaction, is diminished, and urea is found in the serum. The search after this substance has not always been successful, but its presence has been clearly shown by Rainy,¹ O'Shaughnessy,² Mar-chand,³ and myself.

The following are the leading physical characters of the blood in this disease. It appears to be thicker than usual, and either forms a soft, friable clot, or else coagulates very imperfectly.

Wittstock has made a careful analysis of the blood during cholera. In its external characters it resembled healthy blood: the clot was of a scarlet red colour on the surface, but darker than usual in the interior.

His analysis gave the following results: serum 96·5%, clot 63·5%. The specific gravity of serum was 1·0385, and 100 parts left 13·75

¹ London Medical Gazette, Jan. 1838.

² Ansdell's Lectures on the Blood. The Lancet, 1840, p. 840.

³ Poggendorff's Annalen, vol. 49, p. 336.

of solid residue. The clot, when treated with absolute alcohol, left a residue of 31g; the alcohol took up solid crystalline, and thin fluid fat, chlorides of sodium and potassium, lactates of soda and ammonia, extract of flesh, and traces of phosphate of lime. By washing the clot, 6g of fibrin were obtained. Hence, if we consider the fluid of the clot to be serum, we have the composition of this blood expressed as follows:

Water	-	-	-	-	-	740.00
Solid residue	-	-	-	-	-	260.00
Fibrin	-	-	-	-	-	11.00
Albumen	-	-	-	-	-	110.42
Blood-corpuscles	-	-	-	-	-	124.46
Extractive matters and salts	-	-	-	-	-	14.10

The blood-corpuscles, therefore, fall below Lecanu's average, while the albumen and solid constituents, generally, are considerably increased.

Lecanu¹ has made several experiments upon the quantity of solid constituents in the blood in cholera, and has arrived at the following results:

Solid constituents	-	340	251	520	330
Water	-	680	749	480	670

O'Shaughnessy² has analyzed the serum of the blood in this disease, and has detected a considerable quantity of urea in it.

1000 parts were composed of,

Water	-	-	-	-	-	-	-	854.0
Albumen	-	-	-	-	-	-	-	133.0
Urea	-	-	-	-	-	-	-	1.4
Crystalline and fluid fat	-	-	-	-	-	-	-	1.4
Chlorides of sodium and potassium	-	-	-	-	-	-	-	4.0
Sulphates and muriates	-	-	-	-	-	-	-	1.6
Extractive matter and albuminate of soda	-	-	-	-	-	-	-	4.8

I analyzed the blood of a woman labouring under a severe attack of sporadic cholera.

1000 parts of blood contained:

		Analysis 40.
Water	-	750.530
Solid constituents	-	249.470
Fibrin	-	2.470
Fat	-	5.434
Albumen	-	114.114
Hemato-globulin	-	108.529
Extractive matters and salts	-	10.631

The salts amounted to only 5.41, the average quantity being from 7 to 8 in 1000 parts of blood. We see that the water is decidedly diminished, but the ratio of the blood-corpuscles to the albumen is not such as was formerly supposed.³ In consequence of suppression of the urinary and biliary secretions, the blood contained a quantity of urea and of the constituents of the bile, (bilin and biliverdin.)

¹ Etudes Chimiques, etc., p. 106.

² Ancell's Lectures on the Blood. Lancet, 1840, p. 840.

³ It was conceived that the thick and often imperfectly coagulated blood must be very rich in corpuscles, in consequence of the amount of serum thrown off by the intestinal canal.

[Heller examined the blood taken after death from the carotids of a man who died of sporadic cholera.

It was of a very dark colour and of a tolerably thick consistency.

Under the microscope the blood-corpuscles appeared hacked at the edges, as if the capsules were partially destroyed, and many fat-vesicles were seen.

The blood was very rich in albumen, in fat, and in urea. The fixed salts, especially the chlorides, were increased,¹ and the fibrin appeared to be beneath the normal stand. There was no trace of biliphaein.]

II. SUGAR IN THE BLOOD: MELITÆMIA.

The blood in diabetes has been found by several observers, and in one instance by myself, to contain a larger proportion of solid constituents than healthy blood: others, as Lecanu and Henry, state that the amount is smaller. According to the latter, the quantity of blood-corpuscles is diminished, while others assert that they are increased. The fibrin remains at about the normal quantity. Rollo was, I believe, the first who proved the presence of sugar in the blood during diabetes. Gueudeville,² Vauquelin, Segalas,³ Wollaston, Henry and Soubeiran, could not detect it. Bouchardat,⁴ however, directs attention to the important consideration that the presence of sugar in the blood can only be incontestably proved when venesection has been performed two or three hours after dinner, and that if blood is drawn in the morning, no traces of it can be found: I have corroborated this observation.

I have analyzed the blood in three cases of diabetes. The sugar was sought for in the manner described in page 156.

	Analysis 41.	Analysis 42.	Analysis 43.
Water	734-663	789-480	802-000
Solid constituents	205-337	210-510	198-000
Fibrin	2-432	2-370	2-030
Fat	2-010	3-640	2-250
Albumen	114-570	86-000	97-450
Globulin	66-300	98-500	74-350
Hæmatin	5-425	5-100	3-700
Sugar	2-500	a trace	a trace
Extractive matters and salts	9-070	14-900	12-680

The blood in analysis 41 was obtained from a man aged 50 years, who had taken a full meal of animal food two hours previous to being bled. The 2-5 parts of sugar were not perfectly pure; they contained extractive matter, and some salts.

The blood in analysis 42 was taken before dinner from a girl aged 20 years. The presence of sugar was only just perceptible by the

¹ In consequence of the torpidity of the urinary secretion.

² Annal. de Chemie, vol. 44, p. 45.

³ Journal de Chemie Médicale, vol. 1, p. 1.

⁴ Revue Médic. 1839, p. 321.

taste, by the sulphuric acid test, and by the odour evolved on burning it. The disease in this case was far advanced, and it is worthy of remark that, six or eight days previous to dissolution, the diabetes sapidus became converted into diabetes insipidus.

This patient made an extremely large quantity of water, which was not very abundant in sugar; while the man, aged 50, passed only two or three quarts of urine daily, containing a large proportion of sugar.

The blood in analysis 43 was taken before dinner from a man aged 30 years, who passed a very large quantity of water, which, however, did not contain much sugar.

I give, in the following table, the analyses of other observers:¹

	Bouchardat.	Henry and Soubeiran.	Lecanu.
Water	808-76	816-50	848-35
Solid constituents	191-24	183-50	151-65
Fibrin	1-95	2-43	
Albumen	62-54	55-48	58-47
Blood-corpuscles	118-25	120-37	85-18
Salts	852	557	800

I further add the following analysis of the serum in diabetes, made by Rees.²

Water	-	-	-	908-50
Albumen, with a trace of phosphate of lime and peroxide of iron	-	-	-	80-35
Fat	-	-	-	0-95
Diabetic sugar	-	-	-	1-60
Alcohol-extract and urea	-	-	-	2-20
Albuminate of soda, alkaline chlorides and carbonates, with a trace of sulphates and phosphates	-	-	-	0-80

[Some very important additions to our knowledge of the pathology of this obscure disease will be found in Dr. Percy's 'Observations and Experiments concerning diabetes mellitus.' Med. Gaz. vol. ii 1843.]

III. BILE-PIGMENT IN THE BLOOD: CHOLEMIA.

Very contradictory statements exist regarding the composition of the blood in icterus.

Orfila³ found bile, or at least, biliary resin, in the blood of three persons suffering from icterus; and Collard de Martigny⁴ and Clarion⁵ obtained similar results. Lassaigne⁶ and Thenard,⁷ on the contrary, declare that they could never detect any constituent of the bile in such cases. Chevreul found, in the blood of children with icterus, the colouring matter of the bile, but not picromel; and Boudet and Lecanu have likewise found the bile-pigment present in these cases.

¹ In addition to those quoted in the text, there is an analysis of diabetic blood by Müller in the Archiv. d. Pharm., vol. 18, p. 55. Its extremes peculiarly renders its correctness doubtful.

² Ancell's Lectures on the Blood. The Lancet, 1840, p. 889.

³ Éléments de Chim., vol. 2, p. 313.

⁴ Journ. de Chim. Méd., vol. 3, p. 423.

⁵ Thèses d'Ecole de Médecine, 1811.

⁶ Journ. de Chim. Méd., vol. 1, p. 266.

⁷ Traité de Chim., vol. 5, p. 111.

I was fortunate enough to obtain a specimen of the blood of a woman in our hospital who was jaundiced to a degree not often witnessed. The skin over the whole body was of a yellowish brown colour, the urine was of a deep, dark brown tint, and deposited a considerable quantity of brown and yellow sediment. The blood was drawn from the arm in my presence, and was immediately whipt.

It hardly differed in appearance from normal blood, but contained very little fibrin, and the corpuscles speedily sunk. The serum was of an almost blood-red colour, but, when only a thin stratum was viewed, it appeared of a bright amber tint. Its taste was hardly at all bitter; when treated with nitric acid, a whitish yellow coagulum was first formed, (consisting of albumen,) which rapidly assumed a deep grass-green colour, then, after a short interval, changed into a blue, and afterwards into a pale red; and from that to a yellow.

I precipitated the protein-compounds, by means of alcohol, from a large quantity of serum, evaporated the fluid, again treated the residue with alcohol, evaporated, and then dissolved the residue in water. This aqueous solution must have contained bilin or bilisellinic acid (if they had been present), besides the alcohol-extract of the blood and certain salts, but it neither tasted bitter, nor when digested with sulphuric acid, did it yield a resinous substance (a compound of sellinic and cholinic acids and dyslysins;) neither did it contain bilin nor any of the products of its metamorphosis. On the other hand, I found, in the urine of this person, which was brown, very acid, and contained a large quantity of uric acid, a very appreciable quantity of biliary resin.

We can only account for the occurrence of this product of the metamorphosis of bilin in the urine, by recollecting the facility and rapidity with which noxious matters are eliminated from the blood.

My analysis of the blood in icterus gave the following results:

	Analysis 44.
Water	770000
Solid residue	230000
Fibrin	1500
Fat	2640
Albumen	120500
Globulin	72600
Hæmatin	4840
Hæmaphæin, with biliphein	2640
Extractive matters and salts, with biliphein	16500

The peculiarities of this blood are, its large amount of solid constituents, due to an increase, not of the corpuscles, but of the albumen, the diminished quantity of fibrin, and the excess of colouring and extractive matters and salts. In other analyses of the blood I have frequently found it impossible to separate the hæmaphæin from the hæmatin, in consequence of the small amount of the whole colouring matter; in this instance, however, I was able to effect their separation, and it appears that the amount of the hæmaphæin is about one half

of that of the haematin, a proportion which is probably larger than occurs in healthy blood. The fat was not particularly increased.

The researches of Denis and Lecanu give, to a certain degree, similar results: they show a decrease of the blood-corpuscles, but not an increase of the solid constituents.

		Lecanu.		Denis.
		1.	2.	
Water	- - - - -	828-660	830-0	815-00
Solid constituents	- - - - -	171-340	170-0	185-00
Fibrin	- - - - -			9-50
Fat	- - - - -			6-00
Albumen	- - - - -	76-800	65-0	53-00
Blood-corpuscles	- - - - -	79-620	97-0	93-95
Salts	- - - - -			8-00
Yellow and blue pigment	- - - - -			14-55
Salts, extractive matters, and fat	- - - - -	14-900	8-0	

The large amount of fibrin and of fat is remarkable in Denis's analysis; the 14·5 parts of colouring matter were probably combined with extractive matter.

Tiedemann and Gmelin observed that the clot of icteric blood was of the ordinary colour. The clear yellow serum contained biliphaein, and gave, when treated with a small quantity of hydrochloric acid, a hyacinth-red colour, which in the course of the night, became green; if an excess of acid was used, a hyacinth-red colour was at once produced, which, in the course of the night, turned to a blue. When treated with a quantity of nitric acid not sufficient to precipitate the albumen, it became of a greenish yellow colour; when treated with an excess of the acid, it gave a green precipitate, which afterwards became blue, and subsequently violet, red, and yellow.

[Becquerel and Rodier observe that, in icterus, there may be a continued secretion and flow of bile, or there may be perfect retention arising from biliary calculi, &c.

In the first case, no peculiar modification is observable in the blood, and it is, therefore, unnecessary to quote their analyses; in the second case, there is an accumulation of cholesterol and of the other fatty matters in the blood.

The following analysis was made of the blood of a young man, aged 23 years, in whom icterus was developed as a consequence of indigestion. There was constipation, and no appearance of bile in the faeces. The blood contained, in 1000 parts:

Water	- - - - -	740-509
Solid constituents	- - - - -	259-491
Fibrin	- - - - -	1-900
Fat	- - - - -	3-646
Albumen	- - - - -	66-300
Blood-corpuscles	- - - - -	164-300
Extractive matters and salts	- - - - -	23-345

The fatty matters amount to more than double the normal quantity, and consisted of:

Serolin	-	-	-	0.070
Phosphorized fat	-	-	-	0.810
Cholesterin	-	-	-	0.627
Saponified fat	-	-	-	2.139

The fatty acids that enter into the composition of the saponified fat occur in the bile, combined with soda. The salts were normal.

In another case of a similar nature, the fat amounted to 4.176, consisting of:

Serolin	-	-	-	-	0.128
Phosphorized fat	-	-	-	-	1.159
Cholesterin	-	-	-	-	0.556
Saponified fat	-	-	-	-	2.333

In addition to the large amount of fat in the blood in these cases, Becquerel and Rodier observed that the serum was always tinged with bile-pigment.]

IV. FAT IN THE BLOOD; PIARHÆMIA.

It is well known that free fat in the form of globules is not ordinarily seen in healthy human blood. The greater part exists in a saponified state, with the exception of cholesterin and serolin, which do not saponify with potash. As, however, the chyle contains a large quantity of free fat soon after the act of digestion, we must conclude that during the process of metamorphosis of the blood the greater part becomes converted into fatty acids. In certain pathological states of those organs which play an active part in the metamorphosis of the blood, and whose cells contain a considerable quantity of fat, as the liver and kidneys, and during inflammatory affections of the peritoneum and of the lungs, so large a quantity of both free and combined fat is sometimes found in the blood, that the serum appears turbid, opaque, and even milky.

Marcet found the serum milky in diabetes, Trail in hepatitis, Zanarelli in pneumonia, Christison in dropsy, icterus, and nephritis; moreover, in cholera, the blood has been found to be very abundant in fat.

It is hardly necessary to observe that if in such cases the serum appear turbid, whey-like, or milky, fat-globules will be perceptible under the microscope.

Christison and Lecanu¹ have found that this, like most of the animal fats, consists of olein, margarin, and stearin; there is little doubt but that fatty acids are also present; in fact, Lassaigne detected a fat of this nature in the blood, similar to the fatty matter of the brain.

Zanarelli² found the blood of a man with pneumonia similar to milk; it separated into a thicker and a thinner portion. Blood taken some days afterwards separated into a red clot and into a milky serum. Zanarelli is of opinion that this milky blood is chyle, which

¹ Etudes Chimiques, p. 116.

² Journal de Chimie Medic., vol 2, p. 551.

has not been converted into proper blood, in consequence of the affection of the lungs. Bertazzi analyzed it, and his results are given below.

Bertazzi's Analysis of Milky Blood.

Water	-	-	-	-	-	905.0
Solid constituents	-	-	-	-	-	95.0
Crystalline fat	-	-	-	-	-	4.0
Non-crystalline fat	-	-	-	-	-	6.0
Extractive matter, lactates, and chlorides	-	-	-	-	-	5.0
Carbonates, phosphates, and sulphates,	-	-	-	-	-	4.0

Dr. Sion¹ observed an instance of milky blood in a case of mammary abscess. It contained no fibrin, and when allowed to stand a small quantity of colouring matter was deposited. The fluid was analyzed by Lecanu, and the following are the results he obtained:

Lecanu's Analysis of Milky Blood.

Water	-	-	-	-	-	794.0
Solid constituents	-	-	-	-	-	20.60
Albumen	-	-	-	-	-	6.40
Fat; cholesterolin, margarin, stearin, and fatty acids	-	-	-	-	-	117.0
Salts and extractive matters	-	-	-	-	-	25.0
Hemato-globulin	-	-	-	-	-	a trace

In a case of milky serum, which occurred during hepatitis, Trail found:

Water	-	-	-	-	-	789
Albumen	-	-	-	-	-	157
Oily fat	-	-	-	-	-	45
Chlorides and lactates	-	-	-	-	-	9

V. PUS IN THE BLOOD; PYOHEMIA.

According to Gulliver,² pus is found, and probably is also formed, in the blood in all diseases in which there is suppuration, or even inflammatory swelling, accompanied with hectic fever. According to Blandin, blood of this nature, in issuing from the vein, does not differ much in appearance from ordinary blood; it is frequently, however, rather darker and more fluid. When the blood is inflamed and purulent, a muddy or greenish yellow inflammatory coat is formed, in which, according to Piorry, gray granulations of a puriform appearance occur.

Ammonia has been recommended by Donne as a test for the presence of pus in the blood. Blood treated with ammonia dissolves into a clear fluid, while pus similarly treated forms a stiff jelly. If, therefore, blood contains pus, it will become more or less gelatinous upon the addition of ammonia, and if only a very small quantity of pus is present, then we shall only find stripes of this stringy substance deposited at the bottom of the vessel. I have obtained favourable results from this method when the quantity of pus has not been very minute; I will not, however, venture to assert that certain results can be obtained by this method when the amount of pus is extremely small.

¹ Lancette franc. 1835, No. 49.

² Lond. and Edin. Phil Mag. 1838.

Gulliver,¹ Gluge,² and many others have availed themselves of the microscope for the detection of pus in the blood, and I am inclined to believe that this method gives the most certain results. The blood contains, in addition to its own corpuscles, the so-called chyle-corpuscles, which are one half, or even quite, as large again as the blood-corpuscles. They do not possess the yellow colour of the latter; they are gray, only slightly granular, and possess a sharp, dark, circumscribed edge; their rolling motion, on inclining the stage of the microscope, shows that they are perfectly spherical, and they do not, like the blood-corpuscles, dissolve in water. If, however, the chyle-corpuscles remain in contact with water for some time (from half an hour to an hour,) they undergo a change; they increase a little in size, become clearer, their edge appears less sharp, their shape is no longer spherical, but oblong or irregular, and they become more distinctly granular, or else dark points become apparent in the interior, as indications of nuclei. In this condition the chyle-corpuscles may be easily mistaken for pus-corpuscles; the latter are, however, usually rather larger than the tumefied chyle-corpuscles, and they are paler, their edge is granular, or tuberculated, and often very uneven, their shape is round, or oblong, occasionally irregular, and they appear slightly granular in the interior, indicating from three to five nuclei. In very many cases we see two, three, five, or even more pus-corpuscles lying closely attached to each other, while the chyle-corpuscles almost always swim about separately. By this means I have recognised pus in the blood, both when it has been artificially placed there, and on analyzing the blood which I took from the inflamed vein of a person who had died from phlebitis.

In one instance, in which I found a considerable quantity of pus in the blood, taken from the inflamed vein in a case of traumatic phlebitis, I could detect no traces of pus in the blood taken from the vena cava and from the heart.

This is all that I can state from my own experience regarding the detection of pus in the blood.

VI. ANIMALS IN THE BLOOD.

Early authors speak of living animals in the blood. Dr. Chiaje,³ of Naples, has recently stated that he found the polystoma sanguiculum in the expectorated blood of two phthisical patients who were attacked with hæmoptysis. Some of these small flat worms, which are similar to leeches, were floating about in the serum, others attached themselves to the sides of the vessel. Chiaje characterizes the polystoma in the following terms: "Corpus teretiusculum, seu depresso, pori sex antici ventrales, et posticus solitarius; habitat in

¹ Op. cit.

² Fragmente zur Pathologie des Blutes. Anatomisch-Mikroskopische Untersuchungen. Heft 1. 1839.

³ Omodei, Annali universali, Oct. 1837.

venoso systemate hominis, et præsertim in ejusdem pulmonali parenchymate."

[Dr. Goodfellow has lately recorded a case in which an immense number of animalculæ were found in the blood of a fever-patient. They varied in length from 1-5000th to 1-3000th of an inch, and in diameter, which was the same throughout, from 1-40,000th to 1-20,000th of an inch. A singular case was observed by Mr. Bushman, in which worms of about half an inch in length were found in the blood of a boy labouring under influenza.—Ancell's Lectures on the Blood. 'Lancet,' 1840, p. 778.]

SUPPLEMENT.

The following analyses of the blood of a pregnant woman (in her fifth month,) and of menstrual blood, could not be naturally inserted among either of our four forms of diseased blood, and will find a proper place in a supplement.

The blood of the pregnant woman formed a slight buffy coat, but otherwise differed in no respect physically from normal blood.

It was composed of:

	Analysis 45.
Water - - - - -	806-898
Solid constituents - - - - -	193-102
Fibrin - - - - -	2-102
Fat - - - - -	3-040
Albumen - - - - -	72-200
Hæmato-globulin - - - - -	96-900
Extractive matters and salts - - - - -	7-980

The chief point of difference between this and normal blood is that, in this case, the amount of solid constituents is somewhat below the standard. The proportion of the hæmato-globulin to the albumen is normal; the quantity of fat is rather increased.

[Becquerel and Rodier analyzed the blood of nine pregnant women, viz. one at the fourth month, five at the fifth month, one at five months and a half, one at six months, and one at seven months.

The maxima, minima, and mean results are given in the following table:

	Mean.	Max.	Min.
Density of defibrinated blood - - - - -	1051-5	1055-1	1046-2
Density of serum - - - - -	1025-5	1026-8	1023-6
Water - - - - -	801-6		
Fibrin - - - - -	3-5	4-0	2-5
Albumen - - - - -	66-1	68-8	64-4
Blood-corpuscles - - - - -	111-8	127-1	87-7
Extractive matters and salts - - - - -	6-6	8-7	4-7
Fat - - - - -	1-922	2-519	1-158
Consisting of—Serolin - - - - -	variable	0-108	0-018
Phosphorized fat - - - - -	0-646	0-863	0-381
Cholesterin - - - - -	0-061	0-225	0-030
Saponified fat - - - - -	1-195	1-323	0-737

The salts in 1000 parts of blood consisted of:

Chloride of sodium	-	-	3·2	3·9	23
Other soluble salts	-	-	2·4	2·8	1·8
Phosphates	-	-	0·425	0·690	0·282
Iron	-	-	0·449	0·490	0·370

From these analyses they conclude that pregnancy exercises a marked influence on the composition of the blood. The density both of the defibrinated blood and of the serum is diminished, the water, the fibrin, and the phosphorized fat¹ are increased, while the corpuscles and the albumen are diminished.]

The menstrual blood was obtained at a period at which it contained no epithelium scales. It did not coagulate; it contained some vaginal mucus, but it was not putrid or of an unpleasant smell.

It was composed of:

	Analysis 46.
Water	785·000
Solid constituents	215·000
Fat	2·580
Albumen	76·540
Hæmato-globulin	120·400
Extractive matters and salts	8·600

The most striking peculiarities of this blood are, the total absence of fibrin, and the increase of the solid constituents caused by the excess of the blood-corpuscles. The hæmato-globulin was found to be very rich in hæmatin, combined, undoubtedly, with a considerable amount of hæmaphæin; the colouring matter amounted to 8·3% of the hæmato-globulin.

[In an analysis made by Denis, and quoted by Raciborski in his *Essay on Menstruation*, (in *l'Expérience*, No. 333,) the menstrual fluid was found to consist of:

Water	-	-	-	-	-	825·0
Solid constituents	-	-	-	-	-	175·0
Fibrin	-	-	-	-	-	0·5
Phosphorized fat	-	-	-	-	-	3·9
Albumen	-	-	-	-	-	48·3
Blood-corpuscles	-	-	-	-	-	63·4
Mucus	-	-	-	-	-	45·3
Osmazome and cruin	-	-	-	-	-	1·1
Soluble salts	-	-	-	-	-	9·5
Earthy phosphates and carbonates	-	-	-	-	-	2·5
Peroxide of iron	-	-	-	-	-	0·5

Rindskopf analyzed the menstrual discharge of a vigorous and healthy girl. It was extremely acid, and contained:

	1st Analysis		2d Analysis.
Water	820·630	Water	822·692
Solid residue	179·170	Albumen and hæmato-globulin	156·457
Salts	10·150	Extractive matters and salts	20·651

Vogel analyzed the menstrual discharge in the case of prolapsed uterus. It was of an intensely red colour, thick, and viscid: it did

¹ The phosphorized fat is always abundant in impoverished blood.

not coagulate, but, after standing for some time, a colourless serum separated. The fluid obtained at the commencement of the flux yielded 83.9 parts of water and 16.1 of solid materials, and that obtained near the termination yielded 83.7 of water and 16.3 of solid materials. The serum contained 93.53 parts of water and 6.47 of solids, of which 0.64 were fixed salts. There can be little doubt that there is fibrin in the menstrual secretion; its determination is, however, usually rendered impossible by the presence of a large amount of mucus, which seems to deprive the blood of its power of coagulating.

Lochial discharge. Scherer has carefully investigated this subject. The following is a summary of his results.

During the first day the discharge was of a brownish red colour, viscid, formed no coagulum, but, when collected in a vessel, threw down a slimy deposit, consisting of normal blood-corpuscles, with which a few partially-dissolved and broken-up corpuscles, together with mucus-corpuscles and epithelium scales were interspersed. The supernatant serum was clear and yellow, and the microscope revealed in it a large number of fat-vesicles. It was devoid of odour, perfectly neutral, and contained in 1000 parts:

Water	740
Solid constituents	260

On the second day there were still blood-corpuscles, but they were fewer and less perfect, most of them being irregular and indented at the edges; there were mucus-corpuscles and epithelium scales, but in less number than on the preceding day. The fluid still deposited a viscid sediment, but the serum was more highly coloured than on the previous day. The reaction was neutral; there was a faint odour. 1000 parts consisted of:

Water	812.2
Solid constituents	187.8

The residue, on incineration, yielded 9.35 of alkaline ferruginous ash.

On the third day the secretion resembled arterial blood. The blood-corpuscles were, for the most part, perfect, and normal mucus-corpuscles were observed.

In 1000 parts there were:

Water	760
Solid constituents	240

The ash amounted to 12.2. There was an appreciable quantity of fibrin in this day's secretion, arising possibly from a slight haemorrhagic effusion.

On the fourth day the secretion was of a dirty brown colour, the corpuscles were more or less injured, and there was a distinct odour of ammonia. There were numerous mucus-corpuscles, but no epithelium. 1000 parts yielded 191 of solid residue, and 9.5 of alkaline salts.

On the fifth day the discharge was of a greenish yellow colour; it contained very few blood-corpuscles, most of which were more or less injured, but numerous mucus-corpuscles arranged in groups of 5—10 together. The reaction of the fluid was alkaline, there was a strong odour of ammonia, and 1000 parts yielded 93·5 of solid residue.

On the sixth day the fluid was of a brown colour, smelled like putrid cheese, and developed ammonia freely. 1000 parts gave 76 of solid residue. For other analyses and further information on this subject the reader is referred to 'Scherer's Chemische und Mikroskopische Untersuchungzur Pathologie.' Heidelberg, 1843.]

Blood of animals.

In addition to the 12 analyses of horses' blood which have already appeared, I may communicate the three following:

	Analysis 47.	Analysis 48.	Analysis 49.
Water	800-562	818-900	808-809
Solid constituents	199-437	182-100	191-191
Fibrin	4747	5-100	9-011
Fat	5-149	2-214	4-820
Albumen	62-276	62-140	103-740
Hemato-globulin	100-291	96-100	58-960
Extractive matters and salts	12-454	12-310	14-650

The blood in all these analyses was taken from horses suffering from malleus humidus. Analyses 48 and 49 refer to the same horse, but in the latter case the animal was kept for four days without food, being merely allowed water during that period. Taking into consideration the deprivation of nutriment, we cannot help feeling surprised at the large amount of solid constituents that occur in this analysis; it can only be explained by supposing that a larger amount of fluid was removed from the blood by secretion and excretion than was supplied to it by the drink. Another peculiarity is in the increase of fibrin and of fat, and the diminution of blood-corpuscles; this change may, however, be readily explained, for as long as the organs of respiration, secretion, and excretion, continue to discharge their functions, the blood must obviously be changed by them, and this change will especially affect the corpuscles. The horse passed little urine during this time, but this little was tolerably saturated. It was by no means strong at the commencement of the experiment, but at its termination it was much exhausted, and the respiration became gasping. The blood formed a very strong inflammatory crust.

The blood of a healthy ox,¹ and of a healthy calf, yielded the following results:

¹ Berzelius (Thierchemie, p. 98) found, in the serum of the blood of oxen—water, 905, albumen, 80, albuminate of soda and lactate of potash, 6-2, chloride of potassium, 2-6, and modified albumen with carbonate and phosphate of potash, 15.

		Analysis 50.	Analysis 51.
Water	- - -	795-000	777-279
Solid constituents	- - -	205-000	222-721
Fibrin	- - -	-	2-600
Fat	- - -	5-590	4-191
Albumen	- - -	95-050	83-925
Hemato-globulin	- - -	91-710	105-925
Extractive matters and salts	-	11-181	24-444

In the former of these analyses, the fluid which was examined, was a mixture of arterial and venous blood, from which the fibrin had been previously removed: in the latter case the extractive matter was not separated from haematin. The number 105-925 represents the globulin perfectly free from colouring matter.

[Andral, Gavarret, and Delafond, have published a valuable essay on the blood of some of our domestic animals in health and disease. They made no less than 222 analyses of the blood of 155 animals, viz. 41 analyses of the blood of dogs, 31 of horses, 110 of sheep, 2 of goats, 23 of oxen and cows, and 7 of swine.

In order to give an idea of the composition of the blood in the different species of animals, we shall communicate the average, maxima and minima numbers that were obtained. For the principles on which the analyses are founded, see p. 199. Analyses of the blood of 17 horses gave the following results:

	Fibrin.	Blood-corpuscles.	Residue of serum.	Water.
Mean	- - -	40	103-9	810-5
Maximum	- - -	50	112-1	833-3
Minimum	- - -	30	81-5	795-7

Analyses of the blood of 14 neat cattle yielded:

	Fibrin.	Blood-corpuscles.	Residue of serum.	Water.
Mean	- - -	3-7	99-7	810-3
Maximum	- - -	4-4	117-1	834-9
Minimum	- - -	3-0	85-1	799-0

The mean results of the blood of 6 bulls (1,) and of an equal number of milch cows (2,) indicated no important differences.

	Fibrin.	Blood-corpuscles.	Residue of serum.	Water.
(1.)	- - -	3-6	97-4	813-2
(2.)	- - -	3-6	101-9	807-5

Analyses of the blood of 6 swine of the English breed yielded:

	Fibrin.	Blood-corpuscles.	Residue of serum.	Water.
Mean	- - -	4-6	105-7	809-6
Maximum	- - -	5-0	120-6	816-9
Minimum	- - -	4-1	92-1	793-9

The blood of 2 goats gave:

	Fibrin.	Blood-corpuscles.	Residue of serum.	Water.
Mean	- - -	3-2	101-4	804-0
Maximum	- - -	3-5	105-7	809-2
Minimum	- - -	2-6	97-2	798-8

Sheep of various breeds appeared to differ slightly in the composition of the blood.

Analyses of the blood of 19 sheep of the Rambouillet¹ breed yielded:

	Fibrin.	Blood-corpuses.	Residue of serum.	Water.
Mean	- - 3·1	98·1	83·5	815·3
Maximum	- - 3·8	109·6	96·6	830·3
Minimum	- - 2·6	82·5	74·7	808·7

The blood of 11 sheep of a crossed variety, (the Naz-Rambouillet breed,) yielded:—

	Fibrin.	Blood corpuses.	Residue of serum.	Water.
Mean	- - 2·8	106·1	80·3	810·8
Maximum	- - 3·4	123·4	87·7	827·2
Minimum	- - 2·3	94·6	74·7	789·8

The mean results from the blood of these 30 sheep were:

Fibrin.	Blood-corpuses.	Residue of serum.	Water.
3·0	101·1	82·4	813·5

The blood of 13 English sheep yielded somewhat different results:

	Fibrin.	Blood-corpuses.	Residue of serum.	Water.
Mean	- - 2·6	95·0	92·4	810·0
Maximum	- - 3·3	110·4	97·0	822·1
Minimum	- - 2·0	83·8	82·6	795·3

From the blood of 16 dogs² they obtained:

	Fibrin.	Blood-corpuses.	Residue of serum.	Water.
Mean	- - 2·1	148·3	75·5	774·1
Maximum	- - 3·5	176·6	88·7	795·6
Minimum	- - 1·6	127·3	60·9	744·6

The blood was found to offer considerable differences in breeding animals before and after delivery:

	Fibrin.	Blood-corpuses.	Residue of serum.	Water.
Sheep 36 hours before delivery	- 2·3	95·0	81·7	821·0
" 66 hours after delivery	- 3·0	106·2	78·2	812·6
" 24 hours before delivery	- 2·0	92·9	84·5	819·7
" 72 hours after delivery	- 3·5	102·6	86·3	807·6
Cow 5 days before delivery	- 3·7	90·9	75·2	830·2
" 2 days after delivery	- 5·1	98·8	73·7	822·4

That the blood of the lamb differs considerably from the blood of the parent sheep, is obvious from the following analyses:

	Fibrin.	Blood corpuses.	Residue of serum.	Water.
Male lamb, aged 3 hours	- - 1·9	108·6	63·3	826·2
" 24 hours	- - 1·9	117·0	74·2	806·9
" 48 hours	- - 2·5	103·3	80·7	813·5
" 96 hours	- - 3·0	109·1	68·6	819·3

The maxima, minima, and average numbers quoted above, are sufficient to prove that the blood of different species of animals varies in its composition from that of man and of each other. This is a point of no slight importance, for it indicates the necessity that exists for the determination of the constitution of the healthy blood in every individual class of animals before we can venture to draw any conclusions regarding the blood in a morbid state.

¹ A variety of the Merino sheep.

² Gmelin (Handbuch der theoretischen Chemie, vol. 2, p. 1387) found, in the arterial blood of a dog—water, 898, and fibrin, 2·09; the dried serum contained, albumen, 88·3, and salts, 11·7; the venous blood contained, water, 843, and fibrin, 2·1; the dried residue of the serum consisting of albumen, 87·5, and salts, 12·5.

The mean amount of fibrin in one class of animals is as low as 2·1, while in another it rises to 4·6 per mille, one being considerably lower, the other much higher, than in man.

The largest amount of fibrin observed by Andral, Gavarret, and Delafond, was in swine, the maximum being 5·0, and the minimum 4·1; the animals were from 2 to 6 months old, and had been restricted for some time to a diet of horse-flesh. In a two-year old sow that had been fed purely on vegetables, and was very fat, the fibrin did not exceed 4·0. The blood of horses ranks next to that of swine in the amount of fibrin, the observed mean being 4·0, the maximum 5·0, and the minimum 3·0. Next to the horses come neat cattle, the mean amount of fibrin in their blood being 3·7, the maximum 4·4, and the minimum 3·0. The blood of the bull does not contain a larger amount of fibrin than the blood of the cow or the ox. The blood of the Merino sheep contains on an average the same amount of fibrin as human blood,¹ namely, 3·0; in the blood of English sheep a smaller amount of fibrin was obtained. The smallest quantity of fibrin was found in the blood of dogs, the mean being only 2·1, the maximum 3·5, and the minimum 1·6. The minimum occurred in dogs feeding on an exclusive animal diet. From these observations it is evident that each class of animals contains in its blood its own standard amount of fibrin. The blood-corpuscles are found to occur, for the most part, in an inverse ratio to the fibrin; that is to say, in blood that contains a large amount of fibrin, the amount of the corpuscles is small, and *vice versa*. It was shown by special experiments that there is no connexion between the strength of the animal and the amount of fibrin. The amount of fibrin varies considerably before delivery and immediately afterwards, during the milk-fever; in the former case it is at its minimum, in the latter it attains its maximum.

The amount of solid residue of the serum varies between 75·5 and 92·4. The former number occurs in the blood of the dog; the blood of swine, oxen, and Merino sheep, contains from 80·0 to 86·0, and the maximum occurs in the blood of the English sheep.

The investigations of these chemists relating to the blood of domestic animals in a morbid state, were principally confined to sheep suffering from watery cachexia.² We extract the following analyses from their essay, as illustrative of the changes that the blood undergoes in pure hydæmia without any complication.

		Fibrin.	Blood-corpuscles.	Residue of serum.	Water.
A 5 year old sheep:	1st Venesection	- 3·1	44·8	52·7	89·4
	2d	- 3·0	42·2	50·9	90·9
A 6 year old sheep:	1st	- 3·5	46·7	69·5	88·3
	2d	- 3·5	46·6	70·7	87·2
A 6 year old sheep:	1st	- 2·8	49·1	59·1	88·0
	2d	- 2·6	42·4	55·9	89·1
	3d	- 2·9	40·1	58·1	88·1
	4th	- 2·8	67·7	66·6	88·9

¹ Andral and Gavarret always refer to Lecanu's standard.

² Commonly known as the rot.

A 5 year old sheep: 1st	"	- 24	39·4	63·4	894·8
" 2d	"	- 23	33·3	55·8	906·6
" 3d	"	- 30	29·3	52·1	915·6
" 4th	"	- 30	14·2	51·9	930·9

The sheep, whose blood formed the subject of the last analyses, died shortly after the 4th venesection.

In those cases in which the hydramia was associated with inflammatory affections, the blood presented very different characters, as the following analyses will show:

		Fibrin.	Blood-corpuscles.	Residue of serum.	Water.
A 5 year old sheep: 1st Venesection		9·6	329	79·1	878·4
" 2d	"	6·4	300	78·6	886·0
A 4 year old sheep: 1st	"	12·6	39·5	94·1	853·8
" 2d	"	10·4	34·2	89·1	866·3
" 3d	"	8·7	25·3	92·3	873·7
A 4 year old sheep: 1st	"	5·7	60·1	99·1	836·1
" 2d	"	4·3	54·6	95·9	845·2

The first of these animals had, in addition to the hydramia, pneumonia and pulmonary abscess; the second, acute hepatitis and peritonitis; and the third, acute bronchitis.

The following analyses of the blood of sheep, with various disorders, were made by the same chemists:

		Fibrin.	Blood-corpuscles.	Residue of serum.	Water.
Sheep with acute bronchitis	- - -	5·2	61·0	109·4	824·4
Ram with softened tubercles	- - -	4·4	88·8	101·8	805·0
Sheep with tubercular pulmonary cavity	- - -	6·2	64·5	106·7	822·6
Ram with acute enteritis	- - -	6·0	100·7	96·6	796·7
Ewe with acute metritis	- - -	6·3	100·4	85·4	807·9
Sheep with chronic peritonitis: 1st Venesection		3·3	63·2	57·6	875·9
" " 2d "		3·2	56·8	52·2	885·8
" " 3d "		3·1	52·8	52·6	891·5

They remark that the changes which the blood of these animals undergoes in disease, precisely correspond with those of human blood in similar disorders. Thus, in inflammatory diseases, there is always an excess of fibrin, and they observe that in those animals in which the normal mean amount is highest, the fibrin is increased in the greatest proportion; thus in the blood of a cow with inflammation of the respiratory organs, the fibrin rose to 13·0, the normal amount in that animal being 3·8. In dogs that were reduced to a very anaemic condition, the blood-corpuscles fell from the normal mean 148, to 104, and even down to 83.

Their attention was, however, principally directed to the watery cachexia, or rot in sheep. The most prominent phenomena of the disease were extreme debility, paleness of the mucous membranes, and very frequently serous infiltration of the conjunctiva, and of the cellular tissue of the integument of the feet. No albumen was detected in the urine. From 27 analyses made with the blood of 11 sheep, they conclude that the amount of fibrin is slightly affected, but that the blood-corpuscles are excessively diminished; from 78, their normal average, they fall to 40, 25, and even 14. The solid residue of the serum is diminished, (a

point in which this disease differs from chlorosis in the human subject,) and the water is considerably increased.

The deficiency in the amount of blood-corpuses appeared to vary with the progressing weakness of the animal. By proper food, and due attention to atmospheric influences, the corpuscles were observed to increase; in one instance they rose from 49 to 64.

From 14 analyses of the blood, in which this affection was associated with inflammatory disorders, it appeared that the fibrin increases, and the blood-corpuses diminish, as in simple, uncomplicated inflammations.

Lastly, they observed that when venesection was frequently had recourse to in inflammatory affections, each venesection tended to increase the amount of fibrin and of water, and to diminish the quantity of blood-corpuses.

The following are the results of the first and last venesectioins of a horse that was bled seven times in 24 hours:

	Fibrin.	Blood-corpuses.	Residue of serum.	Water.
The 1st Venesection gave	3·1	1040	90·8	802·1
7th " "	7·6	383	60·1	894·2

Nasse has likewise taken up this subject since the publication of Simon's Chemistry.

In the following analyses, which are extracted from his paper, the extractive matters of the blood and the insoluble salts appear to be included with the albumen:

	Water.	Fibrin.	Fat.	Blood-corpuses.	Albumen.	Soluble salts.
Dog - -	790·50	1·93	2·25	123·45	65·19	628
Cat - -	810·02	2·42	2·70	113·39	64·46	701
Horse - -	804·75	2·41	1·31	117·13	67·45	682
Ox - -	799·69	3·62	2·04	121·86	66·90	598
Calf - -	826·71	5·76	1·61	102·50	56·41	700
Goat - -	831·44	3·90	0·91	86·00	62·70	704
Sheep - -	827·76	2·97	1·16	92·42	68·77	691
Rabbit - -	817·30	3·80	1·90	170·72		629
Swine - -	768·94	3·95	1·95	145·35	72·78	674
Goose - -	814·88	3·46	2·56	121·45	50·78	687
Hen - -	793·24	4·67	2·03	144·75	48·25	697

The following table represents the composition of the soluble and insoluble salts occurring in 1000 parts of the blood of these animals:

	Soluble salts:			
	Alkaline phosphates.	Alkaline sulphates.	Alkaline carbonates.	Chloride of sodium.
Dog - -	0·730	0·197	0·789	4·490
Cat - -	0·607	0·210	0·919	5·274
Horse - -	0·844	0·213	1·104	4·659
Ox - -	0·468	0·181	1·071	4·321
Calf - -	0·967	0·269	1·263	4·864
Goat - -	0·402	0·265	1·202	5·176
Sheep - -	0·395	0·348	1·498	4·895
Rabbit - -	0·637	0·202	0·970	4·092
Swine - -	1·362	0·189	1·198	4·281
Goose - -	1·135	0·090	0·824	4·246
Hen - -	0·945	0·100	0·350	5·392

The insoluble salts were found by Nasse to be combinations of

peroxide of iron, lime, magnesia, silica, and phosphoric and sulphuric acids. The magnesia and silica were not determined quantitatively.

In 1000 parts of blood there were :

Insoluble salts:

	Peroxide of Iron.	Lime.	Phosphoric acid.	Sulphuric acid.
Dog	0.714	0.117	0.208	0.013
Cat	0.516	0.136	0.263	0.022
Horse	0.786	0.107	0.123	0.026
Ox	0.731	0.098	0.123	0.018
Calf	0.631	0.130	0.109	0.018
Goat	0.641	0.110	0.129	0.023
Sheep	0.589	0.107	0.113	0.044
Swine	0.782	0.085	0.206	0.041
Goose	0.812	0.120	0.119	0.039
Hen	0.743	0.134	0.935	0.010

The only animals in a state of disease whose blood was analyzed by Nasse were sheep with chronic rot (hydræmia or watery cachexia,) and horses with the glanders. The blood of three sheep affected with the disease in question gave the following results:

	A.	B.	C.
Water	952.00	932.30	916.00
Fibrin	2.75	3.84	3.90
Fat	0.23	0.25	0.30
Blood-corpuscles	10.20	23.40	31.25
Albumen	27.52	32.02	39.45
Soluble salts	7.30	8.19	7.10

The sheep A was very much reduced, and the blood had much the appearance of reddened serum. There was effusion into the peritoneum. The sheep B was pregnant, and in bad condition; while the sheep C had been delivered about 10 weeks previously, and had been since attacked with dropsy. The salts were determined individually, but they presented no peculiar deviation from the normal standard.

The following analyses refer to the blood of two horses A and B, suffering from chronic ozoena (the glanders):

	A.			B.	
	1.	2.	3.	1.	2.
Water	833.00	860.00	842.00	859.00	816.00
Fibrin	8.90	7.50	6.60	8.70	7.90
Blood-corpuscles	65.50	43.30	68.20	44.20	88.50
Albumen and fat	86.58	83.68	76.70	82.27	81.65
Soluble salts	6.02	5.52	6.60	5.38	5.95

The individual salts did not differ in any remarkable degree from the normal standard.

We have already had occasion to refer to the labours of Enderlin, in connexion with the chemistry of the blood. He has recently published the following analyses of the ash of the blood of various animals, which are confirmatory of the views to which we have more than once alluded, respecting the non-existence of lactates in the blood.

The analyses are calculated for 100 parts of ash:

Salts soluble in water:

	Ox.	Calf.	Sheep.	Hare. ¹
Tribasic phosphate of soda (3 NaO, PO ₄)	16.769	30.180	13.296	28.655
Chloride of sodium	-	59.340		
Chloride of potassium	-	6.120	52.650	66.570
Sulphate of soda	-	3.855	2.936	5.385
				3.721

Salts insoluble in water:

Phosphates of lime and magnesia	-	4.190	3.490	
Peroxide of iron and phosphate of ditto	-	8.277	9.277	13.920
Sulphate of lime and loss	-	1.449		0.829

The alkaline carbonates in Nasse's analyses are easily accounted for by Enderlin's explanation of the action of the atmosphere on the tribasic phosphate of soda.]

I have analyzed the blood of the carp and of the tench. In both fishes it was tolerably clear, contained oil-globules visible to the naked eye, formed a loose gelatinous clot, from which scarcely any serum separated, and yielded, on whipping, a viscid sort of fibrin, possessed of little tenacity, and which, on the addition of water, separated into minute flocculi, consisting (according to microscopic investigation) of granular masses and of minute vesicles far smaller than the nuclei of the blood-corpuscles. The blood coagulated imperfectly on boiling, and was remarkable for its small amount of hæmato-globulin. The blood of *bufo variabilis* presented exactly similar phenomena; but on a chemical examination it was found to be richer in solid constituents, especially in albumen, than the blood of fishes. It was impossible to form a quantitative determination of the fibrin or of the colouring matter in the blood of these animals, in consequence of the aplastic character of the former constituent, and the minute quantity of blood that could be obtained.

The analyses gave:

	Analysis 52.	Analysis 53.	Analysis 54. Blood of <i>bufo variabilis</i> .
Water	-	Carp's blood.	Tench's blood.
Solid constituents	-	872.000	900.000
Fibrin	-	129.000	100.000
Fat	-	a trace	a trace
Albumen	-	2.967	4.670
Hæmato-globulin	-	83.850	68.400
Extractive matters and salts	-	24.635	15.650
		6.129	2.770
			2.429

On boiling the dried residue of the blood with spirit, after the removal of the fat, I obtained tinctures of a deep red colour, such as would have been yielded by the blood of the mammalia, but they differed in this respect, that they did not become turbid on cooling, and the hæmato-globulin, instead of being deposited in flocks, had to be determined by evaporation. As the flesh of these animals differs from that of the mammalia, it is by no means impossible that there are corresponding differences in the globulin and hæmatin. The large amount of albumen in the blood of *bufo variabilis* may per-

¹ In another analysis he found bibasic phosphate of soda.

haps be attributed to the unavoidable mixture of the blood with lymph, and perhaps with mucus.

Dumas and Prevost analyzed the blood of numerous animals. The blood was allowed to coagulate, the clot and serum were separately dried, and the serum that remained entangled in the clot was deducted, and added to the serum that spontaneously separated. The fibrin was not determined.

	Water.	Solid constituents.	Blood-corpuscles.	Residue of serum,
Ape: Simia Callitricha	776·0	224·0	146·1	77·9
Dog	-	810·7	189·3	65·5
Cat	-	795·3	204·7	84·3
Horse	-	818·3	181·7	89·7
Calf	-	826·0	174·0	82·8
Sheep	-	829·3	170·7	77·2
Goat	-	814·6	185·4	83·4
Rabbit	-	837·9	162·1	68·3
Guinea pig	-	784·8	215·2	87·2
Raven	-	797·0	203·0	56·4
Heron	-	806·2	191·8	51·2
Duck	-	765·2	234·8	84·7
Hen	-	779·9	220·1	63·0
Pigeon	-	797·4	202·6	46·9
Trout	-	863·7	136·3	72·5
Eelpout	-	886·2	113·8	65·7
Eel	-	846·0	154·0	94·0
Land tortoise	-	778·8	221·2	80·6
Frog	-	884·6	115·4	46·4

[We have already alluded to the occurrence of animalcules in human blood : in the blood of the lower animals such cases are very frequently observed.

Cercaria have been discovered in the blood by Mayer, and in his 'Dissertatio de Organo Electrico et de Hæmatorosis; Bonn. 1843,' he mentions the following: (1,) Paramaecium loricatum s. costatum, in frogs; (2,) Amoeba rotatoria in fishes.¹ Polystoma-like animalcules were described by Schmitz as occurring in the blood of the horse. (Dissertatio de Vermibus in Sanguine, Berol. 1826.)

Gruby and Delafond have described a peculiar animalcule of frequent occurrence in the blood of the dog, and numerous observers have noticed similar phenomena in the blood of the horse and the ^{***} 1

The Lymph.

Our knowledge of the chemical characters of the lymph is very deficient. It is described as a viscid yellow, greenish yellow, and occasionally red fluid, devoid of odour, possessing a slightly saltish taste, an alkaline reaction, containing from 3 to 5·7% of solid constituents. The lymph of the human subject is described by Müller,

¹ Valentin (Müller's Archiv. 1841, p. 436.) frequently detected this animalcule in the blood of the salmon, and once met with it in the fluid of the cerebral ventricles.

Wurtzcr, and Nasse as clear and of a yellow colour, while others assign to it the same tint, but assert that it is opalescent. It coagulates in the course of 10 or 15 minutes into a clear, tremulous, colourless jelly, and deposits an arachnoidal coagulum of fibrin, which was previously held in solution, as in the liquor sanguinis, and is usually colourless, although Tiedemann and Gmelin have observed it of a reddish tint. The fluid left after coagulation is rather thick, resembles almond oil in appearance, and under the microscope exhibits, even when perfectly clear, a number of colourless corpuscles, apparently smaller than human blood-corpuscles, and far less numerous in it than the blood-corpuscles are in the blood. (Müller.) In addition to albumen, the serum of the lymph contains extractive matters and salts: the latter are the same as the salts of the blood.

Gmelin found in 1000 parts of human lymph:

Water	-	-	-	-	-	-	961.0
Solid constituents	-	-	-	-	-	-	39.0
Fibrin	-	-	-	-	-	-	2.5
Albumen	-	-	-	-	-	-	27.5
Chloride of sodium, phosphates of potash and soda, and salivary matter	-	-	-	-	-	-	2.1
Extractive matters and lactate of soda	-	-	-	-	-	-	6.9

Marchand and Colberg have analyzed lymph obtained from a wound on the dorsum of a man's foot. They found in it:

Water	-	-	-	-	-	-	969.26
Solid constituents	-	-	-	-	-	-	30.74
Fibrin	-	-	-	-	-	-	5.20
Albumen	-	-	-	-	-	-	4.34
Extractive matter	-	-	-	-	-	-	3.12
Fluid and crystalline fat	-	-	-	-	-	-	2.64
Chlorides of sodium and potassium, alkaline sulphates and carbonates, sulphate and phosphate of lime, and peroxide of iron	-	-	-	-	-	-	15.44

The amount of fibrin has doubtless been overrated in both these analyses, since the coagulum contains lymph-corpuscles, and some albumen, in addition to that constituent. In Marchand's analysis it amounts to double the quantity in healthy blood. The quantity of albumen is also incorrectly stated, for a fluid containing 43% of albumen does not perfectly coagulate on heating, as this fluid is reported to have done, but merely becomes turbid, and deposits a few flocculi. The salts in Marchand's analysis amount to more than double the amount in the blood.

[L'Heretier (*Traité de Chimie Pathologique*, p. 18,) analyzed the lymph obtained from the thoracic duct of a man who died from softening of the brain, and who took nothing but a little water for 30 hours preceding his death. It contained in 1000 parts.

Water	-	-	-	-	-	924.36
Solid constituents	-	-	-	-	-	75.64
Fibrin	-	-	-	-	-	3.20
Fat	-	-	-	-	-	5.10
Albumen	-	-	-	-	-	60.02
Salts	-	-	-	-	-	8.25]

Dr. Rees has published an analysis of the lymph taken from the absorbents of a young ass immediately after death. He states its constituents to be:

Water	-	-	-	-	-	-	-	965.36
Solid residue	-	-	-	-	-	-	-	34.64
Fibrin	-	-	-	-	-	-	-	1.20
Albumen	-	-	-	-	-	-	-	12.00
Extractive matter soluble in alcohol and in water	-	-	-	-	-	-	-	2.40
Extractive matter soluble in water only	-	-	-	-	-	-	-	13.19
Salts	-	-	-	-	-	-	-	5.65
Fat	-	-	-	-	-	-	-	a trace.

The salts were alkaline chlorides, sulphates, and carbonates, with traces of phosphates, and of peroxide of iron.

Lassaigne analyzed lymph collected from the absorbents of the neck of a horse. He found in it, water, 925.00, fibrin, 3.30, albumen, 57.36, chlorides of sodium and potassium, soda, and phosphate of lime, 14.34.

[The lymph collected from the absorbent vessels of the neck of a horse has been recently analyzed by Nasse. He obtained in 1000 parts:

Water	-	-	-	-	-	-	950.000
Solid residue	-	-	-	-	-	-	50.000
Albumen, with fibrin	-	-	-	-	-	-	39.111
Water-extract	-	-	-	-	-	-	3.248
Spirit-extract	-	-	-	-	-	-	0.577
Alcohol-extract	-	-	-	-	-	-	0.755
Ethereal-extract	-	-	-	-	-	-	0.088
Oleate of soda	-	-	-	-	-	-	0.575
Carbonate of soda	-	-	-	-	-	-	0.560
Phosphate of soda	-	-	-	-	-	-	0.120
Sulphate of potash	-	-	-	-	-	-	0.233
Chloride of sodium	-	-	-	-	-	-	4.123
Carbonate of lime	-	-	-	-	-	-	0.104
Phosphate of lime with some iron	-	-	-	-	-	-	0.095
Carbonate of magnesia	-	-	-	-	-	-	0.044
Silica	-	-	-	-	-	-	0.067

It yielded no microscopic indications of urea. Nasse compared the lymph with the serum from the blood of a healthy horse, and found a remarkable coincidence in the salts of the two fluids:

	Serum.	Lymph.
Alkaline chlorides	-	4.055
Alkaline carbonates ¹	-	1.130
Alkaline sulphates	-	0.311
Alkaline phosphates	-	0.115
	<hr/>	<hr/>
	5.611	5.611

The lymph, therefore, is a dilute serum, and the salts of the blood which make their escape along with the colourless *liquor sanguinis* from the capillaries, either return again in the same proportions to each other as they were secreted, into the capillaries, or, which is most probable, they only penetrate into the lymphatic vessels. Be-

¹ The oleate of soda is calculated as a carbonate.

sides, there being more water in the lymph than in the serum (in the ratio of 950 to 922) the two fluids differ in the ratio of their solid constituents to the salts; in the lymph, the salts amount to 11.22, and in the serum to 9.65 $\frac{1}{2}$ of the solid residue. It is probably this circumstance that causes the much greater viscosity of the serum, which is by no means solely dependent on the larger quantity of albumen in solution.]

All investigations with respect to the motion of the lymph in the absorbents, and to the origin and formation of the lymph-corpuscles, have hitherto been comparatively fruitless. Since the primitive cells of the tissues are now regarded as organized individuals possessing self-dependent powers of selecting their own nutriment, and of discharging the function of secretion, we can no longer refer the passage of the lymph into the terminal points of the absorbents to mere physical endosmosis and exosmosis. I do not believe that we can altogether satisfactorily refer the motion of the lymph to a *vis a tergo*. Whether the lymph is propelled by a progressive contraction of the absorbent vessels, as is maintained by some physiologists, is uncertain; this much, however, is undoubted, that there are numerous valves in the interior of the lymphatics to prevent the regurgitation of their fluid contents. From Weber's observations, it appears that in the tadpole the motion of the lymph is from 10 to 20 times slower than that of the blood.

The Chyle.

True chyle, that is to say, the emulsive fluid that is found after digestion in the lymphatic vessels of the intestinal canal, is usually turbid, and of a white or pinkish tint, but I once observed it of a blood-red colour. It is usually obtained for the purpose of analysis from the thoracic duct, when, although termed chyle, it is in reality a mixture of lymph and true chyle. Chyle, like lymph, coagulates in the course of from 8 to 15 minutes. The clot is soft, gelatinous, and either white (from the entangled fat-vesicles) or red (in consequence of the presence of blood-corpuscles.) The fibrin obtained by whipping fresh chyle is deficient in consistence, being sometimes merely gelatinous, and cannot be washed without suffering loss. The serum of the chyle appears, from my observations, (which were instituted with the chyle of horses) to contain four different sorts of corpuscles, viz. (a) fat-vesicles which occur in large numbers in milky chyle; (b) blood-corpuscles, which may be numerous, few, or absent, according to circumstances; (c) round, colourless, transparent, rarely granular globules, from one-half to three-fourths the size of blood-corpuscles, I have never observed them in the blood; they are the true lymph-corpuscles; and (d) round, gray or colourless granu-

lar corpuscles, with a clearly defined, and not tuberculated outline, half as large again, or occasionally even twice as large as the blood-corpuscles; these are the chyle corpuscles, which are always found in the blood. Fig. 12 exhibits chyle containing numerous blood-corpuscles as seen under the microscope.

Human chyle has never yet been analyzed, but several analyses of the chyle of the lower animals have been made. Through the kindness of Professor Gurlt I have had several opportunities of examining the chyle of horses, and I have made three careful quantitative analyses of it. The method of analysis was precisely the same as for the blood. The fibrin was removed in the usual manner, and washed. A known quantity of the serum was reduced to dryness, and the water thus determined; the residue was finely pulverized, and a portion repeatedly treated with ether, and afterwards with spirit of .915 in order to remove the fat. It was then boiled in water. The residual albumen was dried and weighed. The spirituous and aqueous solutions were mixed and evaporated, and the residue treated with water and dilute spirit, which took up the salts and extractive matters, and left the haemato-globulin. The extractive matters were dried, weighed, and incinerated, and the salts thus determined.

The thoracic duct of a horse that had been kept without food for some time contained only a very small quantity of a reddish fluid, with an alkaline reaction, from which a slight fibrinous coagulum separated, and which, on standing, deposited a red sediment, while the supernatant fluid was clear and yellow. Blood-corpuscles were detected in the sediment, but they were not numerous, and, for the most part, altered in form. Lymph-corpuscles and a very few chyle-corpuscles were observed; some of the latter were of remarkable size, and presented a resemblance to conglomerate fat-cells. 1000 parts of this chyle left a solid residue of 39.5, of which 20 consisted of albumen, and 3.2 of oily fat.

In order to obtain a larger supply of chyle, a horse was fed on peas steeped in water; it was shortly afterwards bled to death, and the chyle collected from the thoracic duct.

I obtained upwards of 600 grains of a reddish yellow alkaline fluid, which was immediately stirred, in order to separate the fibrin. In the serum there was comparatively little fat, and only a small number of blood-corpuscles; while, on the other hand, the lymph- and chyle-corpuscles were abundant. None of the large conglomerate cells observed in the former chyle could be detected.

The analysis of this chyle yielded:

	Analysis 55.
Water	940.670
Solid constituents	59.330
Fibrin	0.440
Fat	1.186
Albumen	42.717
Hemato-globulin	0.474
Extractive matters and salts	8.360
Ptyalin, and globulin or casein, with chloride of sodium and lactate of soda	1.780

The analysis of the salts was not carried out. The amount of solid constituents and especially of albumen, is considerably larger than in the former instance, but the quantity of fat is remarkably small.

On a subsequent occasion I fed two horses with oats soaked in water, and analyzed the chyle thus formed. Both specimens were stirred, in order to remove the fibrin: they had an alkaline reaction, but one was turbid and milky, containing an extraordinary amount of soft but firm fat, while the other was of a blood-red colour, and contained a considerable number of blood-corpuscles. Both specimens contained lymph- and chyle-corpuscles. I have endeavoured, in fig. 12, to represent the corpuscles that were observed in the blood-red chyle.

The analyses of these fluids yielded the following results:

	Analysis 56.	Analysis 57.
	Milky chyle.	Blood-red chyle.
Water	928-000	916-000
Solid constituents	72-000	84-000
Fibrin	0-805	0-900
Fat	10-010	3-480
Albumen with lymph- and chyle-corpuscles	46-430	60-530
Hæmato-globulin	traces	5-691
Extractive matters	5-320	5-265
Alkaline lactates and muriates, with traces of lime	7-300	6-700
Sulphate and phosphate of lime and peroxide of iron	1-100	0-850

These analyses yield a much larger amount of solid constituents than those quoted above: the increase is especially observable in the amount of fat in the former, and in the conjoined amount of albumen and hæmato-globulin in the latter of these analyses. There can be no doubt that these variations are due partly to the nature of the food, and partly to the manner in which chylopoiesis goes on in aged or diseased animals. The salts approximate closely, both in quality and quantity, with those that occur in the blood.

Dr. Rees analyzed the chyle of the same ass to which reference has been already made in page 287. It contained:

Water	902-37
Solid constituents	97-63
Fibrin	3-70
Fat	36-01
Albumen	35-16
Extractive matter soluble in alcohol and water	3-32
Extractive matter soluble in water only	12-33
Salts (similar to those in the lymph)	7-11

[Nasse¹ has instituted the following analysis of the chyle of the cat. It contained in 1000 parts:

Water	905-7
Solid constituents	94-3
Fibrin	1-3
Fat	32-7
Albumen, blood-corpuscles, and extractive matters	48-9

¹ Wagner's Handwörterbuch, vol. 1, p. 235, article 'Chylus.'

Chloride of sodium	-	-	-	-	-	-	-	7·1
Other soluble salts	-	-	-	-	-	-	-	2·3
Iron -	-	-	-	-	-	-	-	traces
Earthy salts	-	-	-	-	-	-	-	20]

The elaborate treatise of Tiedemann and Gmelin affords much information respecting the influence of diet on the qualities of the chyle, and on the modifications that it undergoes in its passage through the mesenteric glands.

Their analyses of the chyle of the horse are given in the following table:

	Water.	Solid constituents.	Clot.	Albumen.	Fat.	Spirit extract, with salts.	Water-extract, with salts.
1	924·3	75·7	17·5	44·45	a trace	7·07	3·60
2	949·8	50·2	4·2	34·27	a little	8·41	2·33
3	918·3	81·7	7·8	42·86	16·12	11·83	2·04
4	967·9	32·1	1·9	19·32	a little	9·19	0·94
5	948·6	57·4	3·1	24·27	12·34	8·33	1·36
6	871·0	129·0	small	35·75		87·07	3·22
7	959·0		41·0	24·60(?)		16·40(?)	3·22

The first four analyses were made with chyle taken from the thoracic duct. The chyle in these cases separated into a bright red clot, and opaque, milky serum. The fifth analysis was made with chyle (taken from the same horse as in analysis 4) after its passage through the mesenteric glands, and the sixth analysis, with chyle, previous to its passage through them. In the former case, the chyle was of a bright red colour, and coagulated perfectly, forming a pale red clot, and a reddish white serum; in the latter, it was white, and coagulated very imperfectly; in fact, instead of there being a clot, there was merely a transparent yellowish film; the serum was white and milky. In the seventh analysis, the chyle was collected from the absorbents of the colon.

The fat in these various specimens of chyle was partly solid, and partly fluid; the salts were apparently the same as in the lymph. The albumen left about $2\frac{1}{2}$ per cent. of ash, which consisted of equal parts of carbonate and sulphate of lime, together with a little carbonate, hydrochlorate, and sulphate of soda. The dried clot, in analysis 2, yielded 9·07 per cent. of brownish red ash, consisting of carbonate, sulphate, and muriate of soda, carbonate and phosphate of lime, and peroxide of iron.

Tiedemann and Gmelin have communicated the following data regarding the influence of diet on the chyle. Their experiments were made on dogs, and the chyle was taken from the thoracic duct.

1. After taking cheese the chyle coagulated very slightly. The clot was little more than a pale red transparent film, and the serum was slightly milky. The chyle contained water 950·3, clot 1·71, residue of serum 48·0.

2. After the use of starch, the chyle was of a pale yellowish white colour, and coagulated rapidly. It contained water 930·0, clot and residue of serum 70·0. The clot was of a pale red colour.

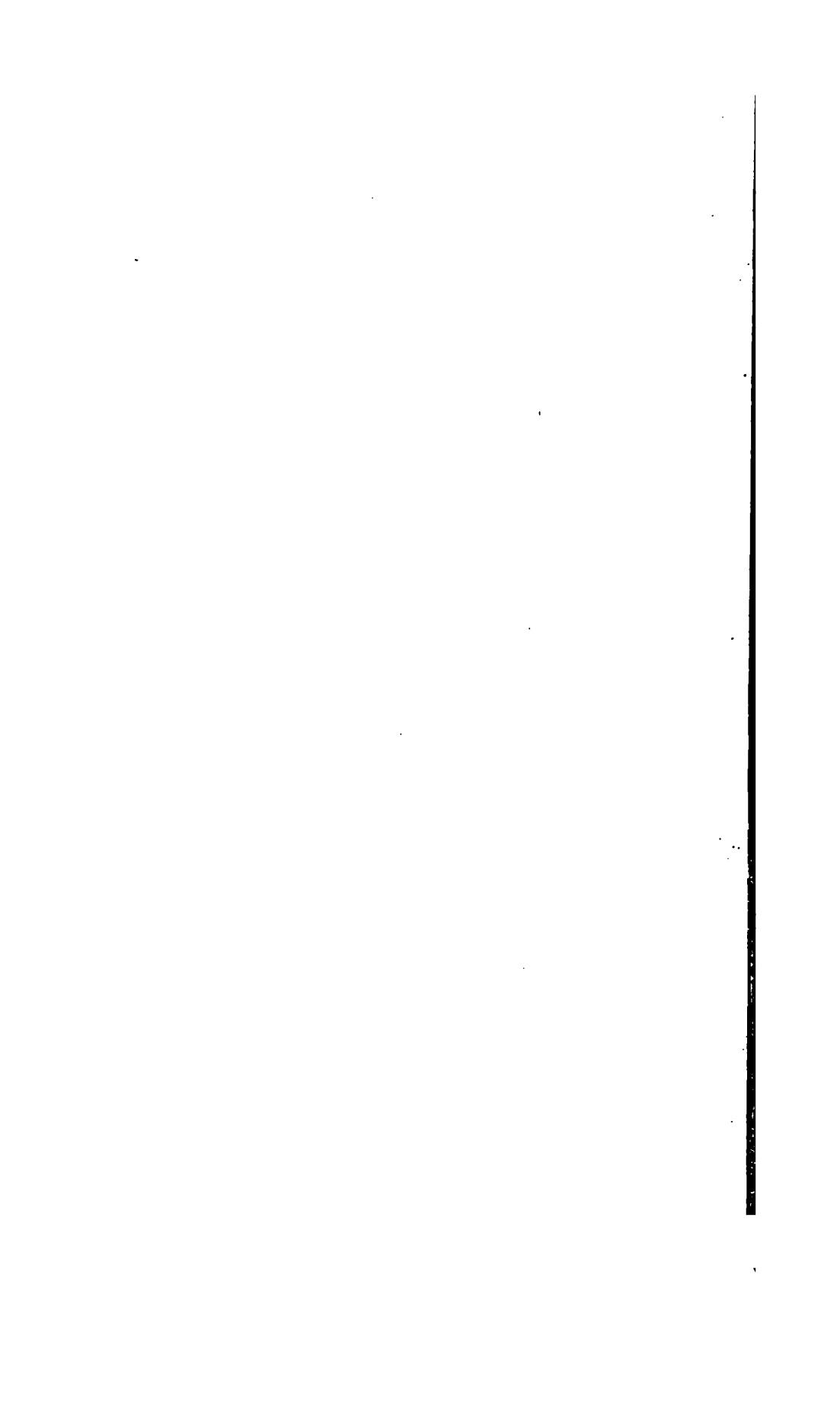
3. After taking flesh, and bread and milk, the chyle was of a reddish white colour, and coagulated rapidly, the clot being of a pale red tint and the serum very milky. It consisted of water, 915·3, clot, 2·7, and residue of serum, 83·8.

4. After the use of milk, the chyle presented a milky appearance, and the clot was transparent and of a pale red colour.

5. After bread and milk, the chyle contained in water, 961·1, clot, 1·9, and residue of serum, 97·0.

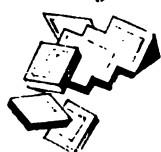
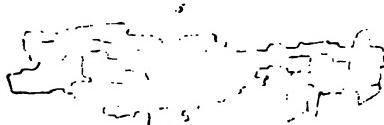
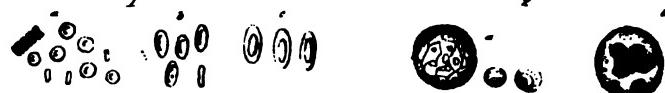
6. After flesh, bread, and milk, the chyle was of a yellowish red colour, coagulated firmly, (separating into a bright red clot and turbid yellow serum,) and contained water, 933·5, clot, 5·6, residue of serum, 60·9.

Any explanation of the results of these investigations would be superfluous, since it is obvious from them, that the food best adapted to dogs, viz. a mixture of flesh, bread, and milk, yields the richest chyle, and increases the amount of clot. That the fibrin is formed in the chyle from the constituents of the food is perhaps less probable than that it is separated from the blood in the lymphatic glands; possibly, chyle of different qualities may react with varying energy on the lymphatic glands.



EXPLANATION OF PLATE I.

- Fig.* 1. Blood-corpuscles of men, birds, and amphibia.
2. The formation of the blood-corpuscles, from Reichert.
3. Urea precipitated from an alcoholic solution by nitric acid.
4. Crystals produced in the alcohol-extract of blood devoid of urea, after the addition of nitric acid.
5. Nitrate of urea from blood in morb. Brightii.
6. Urea precipitated from an alcoholic solution, by oxalic acid.
7. Crystals produced in the alcohol-extract of blood devoid of urea, after the addition of oxalic acid.
8. Crystals of oxalic acid, resembling pure urea.
9. Nitrate of soda.
10. Crystalline groups of nitrate of urea, as it crystallizes from an alcoholic solution.
11. Pus in blood.
12. Chyle from the thoracic duct.



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12



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CHEMISTRY OF MAN.

CHAPTER III.

THE SECRETIONS OF THE CHYLOPOIETIC VISCERA, AND THE THEORY OF DIGESTION.

The Saliva.

THE saliva is a peculiar fluid, secreted by the parotid, submaxillary, and sublingual glands, and conveyed from them by certain ducts into the cavity of the mouth, where it becomes mixed with the buccal mucus. It may, however, be obtained in a state of purity by collecting it as it flows from one of the ducts. The following observations respecting the secretion of the saliva were made by Mitscherlich,¹ on a person with a salivary fistula, in whom the saliva could be collected directly from Steno's duct. He found that there was no flow of saliva while the muscles of mastication and of the tongue were in a state of perfect repose, and all nervous excitement avoided. He likewise observed that, during the acts of eating and drinking, (especially at the commencement,) the secretion was abundant, being proportionate to the stimulating nature of the food and to the degree it was masticated. From two to three ounces of saliva were collected from one of the parotid glands in the course of twenty-four hours. It is usually supposed that about ten or twelve ounces of saliva are secreted daily, but accurate observations are still required on this subject.

Human saliva is a rather opalescent, viscid, colourless fluid; when collected and allowed to rest in a cylindrical glass, it is observed to yield a deposit of epithelium-scales and mucus-corpuses, while the supernatant fluid remains clear. When perfectly normal, its reaction is alkaline; it is devoid of taste and odour, and, when observed under the microscope, is seen to contain peculiar corpuscles, which differ very slightly in their form from tumid mucus-corpuses. The appearance presented by human saliva taken from the mouth, when examined under the microscope, is depicted in fig. 13.

¹ Rust's Magaz. vol. 40.

I have always observed the cells (*a*) in the saliva; they appear to consist of swollen salivary corpuscles. The salivary corpuscles are represented in (*b*); (*c*) represents epithelium-scales; and (*d*) fat-vesicles. Membranous shreds are sometimes observed, apparently fragments of injured epithelium-scales.

The amount of solid residue in the saliva is very small; it is composed of fat, ptyalin, water-extract, spirit-extract, a little albumen, certain salts, and a trace of sulphocyanogen. The presence of the last constituent was first noticed by Treviranus; it has since been detected by Gmelin and Tiedemann, and other chemists.¹

The salts of human saliva are, according to Mitscherlich, chloride of calcium, lactates of soda and potash, soda either free or combined with mucus, phosphate of lime, and silica: according to Gmelin and Tiedemann, they consist, of alkaline carbonates, phosphates, muriates, and traces of sulphates, together with the phosphates and carbonates of lime and magnesia. According to Hünefeld, ammoniacal salts are also present. On evaporating the saliva, we obtain a brown residue, which evolves a rather agreeable odour, resembling that of toasted bread.

In certain pathological states the saliva contains other substances besides those already enumerated: thus, in one case of morbid saliva I detected free acetic acid, and in another I found a considerable quantity of a substance resembling casein.

The albumen contained in the saliva is indicated by the turbidity produced on the application of heat; and after the removal of the coagulated albumen by filtration, the presence of the various extractive matters may be shown by the precipitates thrown down by acetate of lead, bichloride of mercury, and tannin; the casein may be indicated by the addition of acetic acid; ptyalin, and probably casein, by the addition of alcohol to clear and somewhat concentrated saliva; and sulpho-cyanogen, by the redness produced on the addition of perchloride of iron.

With a view to separate the constituents of the saliva, I evaporated a known quantity to dryness, and thus determined the water. I then treated the residue with ether, for the purpose of extracting

¹ The occurrence of this substance in the saliva is equally interesting in a physiological and chemical point of view; and it would be very desirable to establish its presence in an unquestionable manner by experiments on a large quantity of saliva. Gmelin and Tiedemann (*Die Verdauung nach Versuchen*, vol. i. p. 9.) formed an alcoholic extract of saliva, and distilled the residue, after mixing it with phosphoric acid. The fluid obtained by this distillation reddened litmus paper, after some days evolved an odour of prussic acid, yielded a deep yellow-red colour on the addition of perchloride of iron, and precipitates on the addition of nitrate of silver and nitrate of peroxide of mercury. On the addition of sulphate of iron and sulphate of copper to a portion of the distilled fluid, a white precipitate was thrown down, which communicated a red colour to an acid solution of perchloride of iron. The clear chlorine-solution, obtained by mixing chlorate of potash, hydrochloric acid, and chloride of barium, was rendered turbid when digested with a portion of the distilled fluid, and there was a gradual deposition of sulphate of baryta, the sulphuric acid being obtained at the expense of the hydro-sulphocyanic acid. Gmelin and Tiedemann observed the reaction indicating the presence of sulphocyanogen in the saliva of the sheep, and I have noticed it in the saliva of the horse.

the fat; and with water, in order to take up the ptyalin, extractive matters and salts. The insoluble residue that had resisted the action of ether and water, consisted of albumen and mucus. Another portion of the saliva was decanted from its precipitate, evaporated to a small residue, and the ptyalin with a trace of extractive matter, precipitated by alcohol. When the saliva contains a caseous matter, (which I have observed in large quantity in the saliva of the horse,) the precipitate of ptyalin and casein produced by the alcohol must be dissolved in water, and the casein then thrown down by the careful addition of acetic acid. In this case, a portion of the casein precipitated by the alcohol usually remains undissolved by the water. I have detected free acetic acid in the saliva discharged during salivation. In order to determine its quantity, the saliva must be accurately neutralized by a solution of carbonate of potash of known strength; from the amount of the alkaline solution required, the quantity of acetic acid can be calculated. If, in addition to acetic acid, free lactic acid is likewise present, the residue of the saliva, after evaporation, when dissolved in water, will still indicate an acid reaction, because lactic acid differs from acetic acid in not being volatilized at the ordinary temperature used for evaporating animal fluids. In order to determine the amount of free soda in the saliva, the dried residue must be extracted with alcohol; the free soda (which is left in the residue) must be saturated with acetic acid, the resulting acetate of soda extracted with alcohol, evaporated, and by incineration, reduced to carbonate of soda.

An analysis of my own saliva yielded the following results. It contained, in 1000 parts:

	Analysis 58.
Water	991.225
Solid constituents	8.775
Fat containing cholesterol	.525
Ptyalin with extractive matter	4.375
Extractive matter and salts	2.450
Albumen, mucus, and cells	1.400

Berzelius¹ found, in 1000 parts of human saliva:

Water	-	-	-	-	-	992.9
Ptyalin	-	-	-	-	-	.29
Mucus	-	-	-	-	-	1.4
Extract of flesh with alkaline lactates	-	-	-	-	-	.9
Chloride of sodium	-	-	-	-	-	1.7
Soda	-	-	-	-	-	.2

According to the analyses of Tiedemann and Gmelin, 1000 parts of human saliva contain from 9 to 11.4, or even 11.9 of solid constituents, consisting in 100 parts, of phosphorized fat, extract of flesh, chloride of potassium, lactate of potash, and sulphocyanide of potassium, lactate of potash, and sulphocyanide of potassium, 31.25;—animal matter with traces of alkaline sulphates and chlorides, 1.25;—ptyalin, with alkaline phosphates, chloride of sodium, and traces of alkaline sulphates, 20.00;—mucus and a little albumen, with

¹ Thierchemie, p. 219.

alkaline phosphates and carbonates, 40·00. This solid residue yielded on incineration 21·9% of inorganic constituents, 17·8 of which were soluble, and 4·1 insoluble in water. Mitscherlich found that 1000 parts of human saliva yielded from 14·7 to 16·3 of solid residue, of which 34% were insoluble both in water and in alcohol, 42% soluble in water but not in alcohol of ·800, and 24% soluble in water and in alcohol. These proportions varied, however, in different analyses.

The inorganic constituents in 1000 parts of saliva are, according to Mitscherlich, chloride of calcium, 1·8; lactate of potash, .95; lactate of soda, .24; soda, probably combined with mucus, 1·64; phosphate of lime, .17; silica, .15.

[According to Dr. Wright, pure saliva is a limpid fluid, having a faint blue tinge, and a slight degree of viscosity. It is perfectly uniform in consistence, and unobscured by frothiness or flocculi. It possesses a faint sickly odour *sui generis*, due to its constituent, ptyalin: this odour is strengthened by heat and by most acids, but alkalies diminish and destroy it.

The saliva even of healthy people varies considerably in its specific gravity. It is always denser after a meal than during fasting; and generally denser in an evening than in a morning. But the converse is usually the rule with dyspeptics. Dr. Wright found that animal (especially fatty) diet, and alcoholic stimulants, have a tendency to thicken the saliva; oysters, and vegetable diet, he says, produce an opposite effect. He states, as the result of many trials and observations, that healthy saliva is mostly of a sp. gr. of 1007·9. When above 1010·0 or below 1003·0, the secretion may be considered to be morbid. Healthy saliva, he affirms, is either alkaline or neutral, generally the former. If saliva be heated, it not uncommonly acquires an acidity in a few minutes, but this chiefly happens to neutral saliva.

Dr. Wright believes in the existence of the principle called ptyalin, though he separates it from saliva by a new process. This process is "to pass saliva through ordinary filtering paper, and, after filtration shall have been completed, to exhaust the residue with sulphuric ether; the ethereal solution contains a fatty acid ptyalin.¹ It is to be allowed to evaporate spontaneously, and the residue left by evaporation is to be placed upon a filter and acted upon by distilled water, which dissolves the ptyalin and leaves the fatty acid. If the aqueous solution be carefully evaporated to dryness, the "salivary matter will be obtained in a pure state." "Ptyalin," he says, "as thus prepared, is a yellowish-white, adhesive, and nearly solid matter, neither acid nor alkaline, readily soluble in ether, alcohol, and essential oils, but more sparingly soluble in water. It alone possesses the charac-

¹ A reference to page 31, will show that Wright's ptyalin differs in several respects from the ptyalin described by Simon. In truth, little is known regarding this constituent.

teristic odour of saliva; it is unaffected by galvanism and by most of the reagents which coagulate albumen. It is abundantly precipitated by sub-acetate of lead, and nitrate of silver; feebly so by acetate and nitrate of lead, and tincture of galls; uninfluenced by bichloride of mercury and strong acids; the latter considerably heighten its proper odour and impair its solubility, while alkalies render it more soluble, and give it the smell of mucus. Moderate heat and oxygen gas also increase its odour, but a more intense heat or cold diminishes or entirely destroys it. At a suitable temperature, ptyalin may be preserved for any length of time without risk of decomposition. The salivary fluid from which ptyalin has been removed, possesses a sickly mucous smell, decomposes much sooner than ordinary saliva, and, in the process of decay, invariably evolves ammonia. If the fluid be heated, the mucous smell will be increased until the evaporation shall have been continued nearly to dryness, when a slight salivary odour may be recognised, due to a portion of ptyalin being liberated from the mucus with which it was previously in combination."

Dr. Wright says that sulphocyanogen is an invariable constituent of healthy human saliva. He advises that it be sought for in the alcoholic extract of the residue left by the careful evaporation of the fluid, as the mucus, unless removed, offers considerable impediment to the action of reagents. The sulphocyanogen occurs in combination with potassium, the salt constituting generally from .051 to .098 of the secretion. "The proportion," he says, "is temporarily augmented by local stimulation of the salivary glands, as by smoking, chewing sialagogues, &c. It is also increased by the internal use of prussic acid and salts of cyanogen, and remarkably so by the use of sulphur."

Pure saliva absorbs a variable quantity of oxygen. Dr. Wright says, "I have known the quantity absorbed to exceed $2\frac{1}{2}$ times the bulk of the saliva; but I once met with an instance in which the healthy secretion did not absorb more than half its volume of oxygen. The difference is generally dependent upon the carbonic acid gas naturally contained in the saliva, the proportion of which gas to the secretion varies from one eighth to one twelfth in volume, though, in some particular cases, it is much more abundant." He says that saliva, in its healthy state, contains also oxygen gas, which it can be made to evolve on the application of heat. This in some measure aids its digestive powers; for he found that saliva which had been exposed for some hours to an atmosphere of oxygen, converted a much greater quantity of starch into gum and sugar than other saliva which had not been so exposed. This statement, founded upon a great number of comparative experiments, was made by Dr. Wright long before the apparently less correct observation of Liebig, that the saliva collects "bubbles of air" to assist the digestive function. In pure saliva there are no "bubbles of air;" the absorbed gases are carbonic acid and oxygen, the latter only contributing to the digestive properties of the fluid. As the result of numerous analyses,

the process of which Dr. Wright has fully detailed, he gives the following as the constituents of the healthy secretion:¹

Water	:	:	:	:	988·1
Ptyalin	:	:	:	:	1·8
Fatty acid	:	:	:	:	.5
Chlorides of sodium and potassium	:	:	:	:	1·4
Albumen with soda	:	:	:	:	.9
Phosphate of lime	:	:	:	:	.6
Albuminate of soda	:	:	:	:	.8
Lactated of potash and soda	:	:	:	:	.7
Sulphocyanide of potassium	:	:	:	:	.9
Soda	:	:	:	:	.5
Mucus, with ptyalin	:	:	:	:	2·6

L'Heretier has recorded the mean of ten analyses of the saliva of healthy persons, collected while fasting:

Water	:	:	:	:	986·5
Organic matter	:	:	:	:	12·6
Inorganic matter	:	:	:	:	.9

The salivary matter, or ptyalin, formed 2·5 of the 12·6 parts of organic matters.

In children the amount of water is generally increased. As a mean of four analyses, he found:

Water	:	:	:	:	996·0
Organic matter	:	:	:	:	3·5
Inorganic matter	:	:	:	:	.5

The ptyalin amounted to only 1·1.

He was unable to detect any difference between the saliva of man and woman.

Enderlin has made numerous analyses of the ash left after the incineration of the saliva, and has always found it to have the same constituents. He considers that its alkaline reaction is due to the tribasic phosphate of soda (3NaO, PO_4) which retains the mucus and protein-compounds in solution. Enderlin observes that, independently of conclusions deduced from the ash, he has sought unsuccessfully, in a direct manner, for lactates in the saliva. On incinerating salivary mucus obtained by washing that constituent from a filter, the residue is found to consist of phosphate of lime, with traces of chloride of sodium and phosphate of soda, the same composition as the tartar that collects on the teeth.

A quantitative analysis of the ash from a large amount of saliva obtained from different persons, yielded the following results:

A. Constituents soluble in water.

Tribasic phosphate of soda (3NaO, PO_4)	:	:	:	:	28·122
Chlorides of sodium and potassium	:	:	:	:	61·930
Sulphate of soda	:	:	:	:	2·315

B. Constituents insoluble in water.

Phosphate of lime	:	:	:	:	5·509
" magnesia	:	:	:	:	
" peroxide of iron	:	:	:	:	

¹ Der Speichel in physiologischer, diagnostischer, und therapeutischer Beziehung, p. 28, Wien, 1844. Dr. Wright's investigations first appeared in the *Lancet*.

Very little is known with certainty regarding the part taken by the saliva in the process of digestion. Spallanzani fancied that he had observed that food enclosed in tubes pierced with numerous apertures, and moistened by the saliva, was more rapidly digested than when simply moistened with water. Berzelius, however, found that the saliva exerts no greater solvent power than pure water, and Müller confirms his statement. Hünefeld, on the other hand, believes that the object of the saliva is to destroy the tenacity of the food, and he thinks that it has the power of reducing fibrin to the condition of a viscid fluid.

[The services which the saliva performs in the animal economy are classified by Dr. Wright as follow:

Active.—1. To stimulate the stomach and excite it to activity by contact. 2. To aid the digestion of food by a specific action upon the food itself. 3. To neutralize any undue acidity in the stomach by supplying a proportionate alkali.

Passive.—1. To assist the sense of taste. 2. To favour the expression of the voice. 3. To clear the mucous membrane of the mouth, and to moderate thirst.

Mialhe¹ has recently announced the discovery of an active principle in the saliva analogous in its physical and chemical characters to diastase. It is solid, white or grayish-white, amorphous, insoluble in alcohol, but soluble in water and spirit. The directions for obtaining it are the following: Filter saliva and treat it with five or six times its weight of absolute alcohol, adding it as long as any precipitate occurs. This animal diastase is insoluble, and falls in white flocks, which must be collected on a filter and dried. It forms about $\frac{2}{3}$ of the whole saliva.]

Leuchs² was the first who observed that saliva converts boiled starch into sugar.

Morbid Saliva.

The saliva becomes affected in various morbid conditions of the system, but the nature of the changes that it undergoes has not hitherto been sufficiently studied. Morbid saliva sometimes contains a free acid; this is most commonly lactic acid, but, in some cases, acetic acid is likewise present. The acid reaction may be at once detected by test paper; while normal saliva communicates a blue tint to red litmus paper, this, on the contrary, reddens blue paper. I have frequently seen the saliva acid in acute rheumatism, and in cases of salivation. According to Donné,³ the saliva has an acid reaction in all cases of irritation and inflammation of the stomach, in pleuritis, encephalitis, intermittent fevers, acute rheumatism, uterine

¹ Lancette Française, 1845, April.

² Kastner's Archiv. 1831.

³ Arch. Génér. de Méd. 1835, May.

affections, and amenorrhœa. Brugnatelli¹ detected oxalic acid in the saliva of a phthisical patient. The secretion of saliva is sometimes increased to an extraordinary degree, constituting salivation; in such cases, the chemical characters of the saliva are also more or less affected. In a specimen of saliva forwarded to me for examination, which was obtained from a patient who had just terminated a course of mercury of some weeks' duration, I observed an acid reaction arising from the presence of free acetic acid. It was very viscid, of a yellow colour, and possessed a sickly disagreeable, acid smell. It contained no mercury. After evaporation to dryness, all the acid reaction had disappeared: thus showing that it contained no free lactic acid. This saliva contained a very large quantity of semifluid fat, a considerable amount of albumen, and traces of caseous matter. Under the microscope, an immense number of fat-vesicles were seen, some epithelium-cells, and a very few partially-destroyed saliva-corpuscles. 1000 parts of this saliva were composed of:

	Analysis 59.
Water	974·12
Solid constituents	25·68
Yellow viscid fat	6·94
Ptyalin with extractive matter and traces of casein	3·60
Alcohol-extract with salts	7·57
Albumen	7·77

The salts consisted of a largely preponderating amount of the chlorides of sodium and potassium, associated with the lactates of soda and potash, and with a small quantity of the earthy phosphates. On contrasting this saliva with the normal fluid, we are struck with its large amount of solid constituents, arising not from any increase of the ptyalin, but of the fat, the extractive matters, the albumen, and the salts.

[L'Heretier gives the mean of three analyses of this secretion during mercurial ptyalism. He found:

Water	-	-	-	970·0 in place of 986·6
Organic matters	:	:	:	28·6 12·6
Inorganic matters	:	:	:	1·1 1·9

The mean amount of ptyalin was 2·6, or very nearly the normal quantity. He attributes the large amount of organic matter to the increased quantity of mucus secreted by the buccal membrane.

Dr. Wright also found that the saliva of mercurial ptyalism contained an unusual amount of mucus. It consisted of:

Water	-	-	-	-	-	988·7
Ptyalin	-	-	-	-	-	1·9
Fatty acid	-	-	-	-	-	.4
Albumen with soda, and						.6
Albuminate of soda						

¹ Stark, Allgemeine Pathologie, p. 1074.

Mucus with a trace of ptyalin		38
Lactates	-	
Phosphates	-	
Muriates	-	
Hydrosulphocyanates	{ Potash Soda Lime	24

He could not detect the slightest trace of mercury in it.]

Gmelin¹ has examined saliva discharged in consequence of salivation produced by mercurial inunction. In one case it was brown and turbid, and contained a large quantity of fat, but not much albumen; in another it presented a yellow tint: it contained a large quantity of yellow fat, and when heated, gave no perceptible indication of coagulation. In both cases, but most decidedly in the latter, indications of mercury were obtained.² Thomson³ found the saliva resulting from the administration of mercury, turbid; it deposited flocculi of coagulated albumen. It was not precipitable by tannic acid, had a specific gravity of 1003.8, and contained, coagulated albumen, 2.57; mucus, 3.67; chloride of sodium, .9; water, 992.8. Bostock analyzed the saliva of a man who was secreting about two quarts daily in consequence of mercurial salivation. It was of a clear brown colour, neutral, viscid, but not stringy, and barely transparent. It became clear, however, after the deposition of the minute flocculi suspended in it; the application of heat, and also the addition of corrosive sublimate, gave indications of the presence of albumen. It yielded 2% of dried residue. After the discontinuance of the mercury, the saliva was found to be less transparent; it reddened litmus paper, contained more albumen, and more solid constituents generally. Vogel⁴ analyzed the saliva of a man with spontaneous salivation; it contained 991.2 parts of water; 4.4 of ptyalin, osmazome, fat, and albumen; and 4.4 of salts of soda, potash, and lime; hence, in respect to the amount of solid constituents and ptyalin, this saliva did not differ very much from the normal standard. Mitscherlich also found that, in the salivary flow excited by nervous irritation, the amount of the solid constituents was not increased, that the ptyalin and sulphocyanogen were even below the normal standard, while, on the other hand, the extractive matters were somewhat increased. A similar observation has been made by Guibourt.

I examined the saliva of a patient suffering from an inflammatory affection of the pancreas. It was discharged from the mouth in large

¹ Pogg. Ann. 41, p. 438.

² Gmelin employed Smithson's method for the detection of the mercury. A large quantity of saliva was treated with nitric acid, and evaporated; the residue was digested with nitric acid and dissolved in water; and, after the removal of fat by filtration, a stream of sulphuretted hydrogen was passed through it. The precipitate obtained by this process contains sulphuret of mercury; it must be collected, digested in nitro-muriatic acid, evaporated, dissolved in dilute hydrochloric acid, and a bit of gold-leaf enveloped in tin-foil, or encircled by iron-wire, suspended in the fluid. The gold is tarnished if mercury is present. No tin-foil should be used that has not been itself tested for mercury. In place of the gold-leaf I have employed the blade of a knife with advantage.

³ Annals of Philosophy, vol. vi. p. 397.

⁴ Lehrbuch der Physiologie, von R. Wagner, p. 212.

quantity; it was a clear, viscid fluid, mixed with mucus, alkaline in its reaction, and exhibiting, under the microscope, mucus-corpuscles, numerous oil-vesicles, epithelium-cells, and membranous shreds: its specific gravity was 1005; and 1000 parts yielded only ten of solid residue, which, in addition to mucus, and a very small quantity of albumen, consisted principally of an extractive matter which developed an aromatic odour on the application of heat, of fat, certain salts, and a little ptyalin.

[L'Heretier observes that, in chlorosis, the amount of water increases in proportion to the progress of the disorder. An analysis of the saliva in this disease is given in page 299 of his Pathological Chemistry.

In dropsy, with albuminous urine, the saliva contained:

Water - - - - -	985.9
Organic matter - - - - -	13.6
Inorganic matter - - - - -	.5

In most inflammatory affections, the amount of water is diminished. The following numbers express the mean results of six analyses in cases of inflammatory fever, pneumonia, and erysipelas:

Water - - - - -	968.9
Organic matters - - - - -	30.0
Inorganic matters - - - - -	1.1

The mean amount of ptyalin was 3.6; the ordinary amount, according to L'Heretier, being 2.5.

The three following forms of morbid saliva have been analyzed by Dr. Wright:

<i>Fatty saliva.</i>					
Water - - - - -					987.4
Ptyalin - - - - -					.7
Adventitious fatty matter and fatty acid - - - - -					3.9
Albumen with soda, and { aluminate of soda - - - - -					1.5
Sulphocyanide of potassium - - - - -					a trace
Mucus - - - - -					2.4
Lactates - - - - -	{	Potash - - - - -	{		
Muriates - - - - -	{	Soda - - - - -	{		1.8
Phosphates - - - - -	{	Lime - - - - -	{		
<i>Sweet saliva.</i>					
Water - - - - -					986.9
Ptyalin - - - - -					.3
Fatty acid - - - - -					.2
Muco-saccharine matter - - - - -					5.6
Albumen with soda, and { aluminate of soda - - - - -					.4
Sulphocyanogen - - - - -					a trace.
Mucus with a trace of ptyalin - - - - -					2.6
Lactates - - - - -	{	Potash - - - - -	{		
Muriates - - - - -	{	Soda - - - - -	{		1.9
Phosphates - - - - -	{	Lime - - - - -	{		
<i>Bilious saliva.</i>					
Water - - - - -					986.7
Ptyalin - - - - -					.5

Fatty matter and fatty acid	-	-	-	-	-	1.3
Biliary matter	-	-	-	-	-	3.2
Cholesterin	-	-	-	-	-	.4
Albumen with soda, and albuminate of soda	-	-	3	-	-	1.9
Mucus	-	-	-	-	-	1.6
Carbonates	-	2	Potash	-	-	
Muriates	-	2	Soda	-	-	
Phosphates	-	2	Lime	-	-	23]

Saliva of animals.

I have analyzed the saliva of a horse suffering from ozaena. Professor Hertwig kindly assisted me in exposing Steno's duct; and, in the course of eight hours, (during which time the horse was feeding,) about five ounces of saliva were collected from the opened duct. The fluid was viscid, of a faintly yellow colour, devoid of odour, alkaline in its reaction, and possessed a specific gravity of 1006. (Schultz¹ collected in a similar manner 55 ounces 7 drachms of saliva from a horse in the course of twenty-four hours.) After some time, the saliva deposited a white sediment, consisting of irregular membranous shreds and saliva-corpuscles. On the application of heat, it became turbid. A copious precipitate was thrown down on the addition of acetic, dilute sulphuric, or lactic acid; and on evaporation it became covered with a film of coagulated casein. Perchloride of iron produced a vivid red colour, and a slight precipitate. It contained a larger amount of solid constituents than human saliva, and a very considerable quantity of casein, part of which coagulated on evaporation, and part was thrown down by acetic acid; in this manner it was separated from the ptyalin. 1000 parts of this saliva were composed of:

	Analysis 60.
Water	992.000
Solid constituents	16.000
Fat containing cholesterin	.120
Ptyalin with extractive matters	4.442
Casein	5.423
Albumen	.601
Extractive matters and salts	7.178

Saliva of the dog.

The saliva of a healthy dog was collected by exposing Steno's duct, and examined by Gmelin and Tiedemann. It was rather turbid, of a pale yellowish-white colour, thick, capable of being drawn out in threads like albumen, alkaline in its reaction, and 1000 parts left, on evaporation, a solid residue of 25.8, consisting of a little extractive matter soluble in alcohol, an average quantity of ptyalin, mucus, a very large amount of chloride of sodium, together with alkaline carbonates, acetates, sulphates, and phosphates, and a little phosphate and carbonate of lime.

¹ De Alimentorum concoctione. Berol. 1834.

Saliva of the sheep.

Gmelin and Tiedemann succeeded in collecting between three and four ounces of saliva in the course of fifteen hours from the stenonian duct of a sheep. It was of a reddish tint, in consequence of being mixed with a little blood, perfectly fluid, faintly alkaline, and of a slightly saline taste. 1000 parts of the saliva contained:

Water	9890
Extract of flesh, an organic matter with which chloride of sodium crystallized in octohedra, chloride of sodium, and a little sulphocyanide of sodium	1·1
A little ptyalin, with a good deal of phosphate and carbonate of soda, and chloride of sodium	82
Mucus or albumen, with a little phosphate and carbonate of potash	5

The Pancreatic Fluid.

The most accurate analysis of the pancreatic juice is that of Tiedemann and Gmelin.¹ Earlier observers, as, for instance, De la Boë, De Graf, and others, had shown that it is an acid, clear, rather viscid fluid, possessed of a saline or acid-saline taste. Wepfer, Pechlin, and Brunner, on the other hand, had described it as turbid, of a whitish colour, not acid, but having a saltish taste, somewhat like the lymph. Mayer² described the pancreatic juice of a cat as transparent, viscid, decidedly alkaline, and containing albumen, chloride of sodium, and a peculiar animal matter. Magendie found it alkaline and albuminous in a dog, and in birds it contained so large an amount of albumen as to coagulate on the application of heat.

Tiedemann and Gmelin cut down upon the pancreatic duct of a strong well-fed dog, and, in the course of four hours, collected about 155 grains of the fluid secretion. The portion that was first collected was turbid, and somewhat red, probably in consequence of the presence of a little blood. This was placed aside. The subsequent portion had a bluish-white tint; could be drawn out in threads like dilute albumen, had a faintly saline taste, and an alkaline reaction. 1000 parts left 87 of solid residue. The red portion first collected has a faintly acid reaction. The principal constituents were extractive matters, chloride of sodium, albumen, and a sort of modified casein.

The pancreatic juice of a sheep was found by Gmelin and Tiedemann to be clear, slightly acid, and of a faintly saline taste. 1000 parts left 36 of solid residue, consisting of the same ingredients as in the dog. In this instance, also, the portion that escaped during the latter part of the experiment was alkaline, and was richer in solid constituents than the fluid that escaped earlier; it contained 51·9 of solid constituents in 1000 parts.

The following is the result of their analyses:

¹ Op. cit. vol. i. p. 25.

² Deutsh. Arch. für die Physiologie, vol. iii. p. 170.

	In the dog.	In the sheep.
Water	917·2	963·5
Extractive matters and salts soluble in alcohol	36·8	15·5
Caseous matter and soda-salts soluble in water	15·3	2·8
Albumen and salts	35·5	22·4

The alcohol-extract of the pancreatic juice of the dog yielded a very singular reaction. On the addition of a little solution of chlorine to the dissolved alcohol-extract, a vivid rose-red tint was produced, and, in the course of twelve hours, there was a precipitation of delicate violet-coloured flocculi. The colour was immediately destroyed by the addition of an excess of chlorine. An attempt to isolate this colouring matter proved unsuccessful.

Leuret and Lassaigne have analyzed the pancreatic juice of a horse, and the result of their investigation is, that it is almost identical in its composition with human saliva. This statement is so much at variance with the results obtained by Tiedemann and Gmelin, that we must conclude that Leuret and Lassaigne were not sufficiently careful in their investigation.

We are still unable to state with any degree of certainty what part the pancreatic fluid performs in the process of digestion. There can be no doubt that when the pancreas is diseased, the pancreatic fluid must be also affected, but we are perfectly in the dark as to the nature of those changes.

The Bile.

Bilin and urea can hardly be regarded as simultaneous products of the metamorphic action of the blood; for while I have detected small quantities of urea in the blood of a healthy calf, I have never been able to recognise the least trace of bilin or of bile-pigment. Hence, while urea is produced not only in the kidneys but in other parts of the system, bilin seems to be produced and secreted only in the liver.

The bile is a very complicated fluid. According to the latest researches of Berzelius, it contains bilin; cholepyrrhin (or biliphæin;) biliverdin; mucus; cholesterin; oleate, margarate, and stearate of soda; chloride of sodium; sulphate, phosphate, and lactate of soda; and phosphate of lime.

Gmelin and Tiedemann, as well as Frommherz, mention casein and ptyalin, and the carbonates and sulphates of soda and lime, among the constituents of the bile.

A perfect analysis of bile would be a subject of extreme labour and difficulty, and we must, therefore, confine our attention to its most important constituents. Let us suppose that it was required to ascertain the amount of bilin, bilifellinic acid, and cholesterin, in a specimen of bile; the fluid must be first evaporated to dryness, and the amount of water thus estimated; the residue must be repeatedly extracted with ether, the ethereal solution evaporated to dryness, and its residue, consisting of cholesterin and fluid fat, thoroughly washed with cold and not too strong alcohol, which dissolves the greater

portion of the fluid fat. It must then be digested with hot alcohol of 0·83; and as this solution cools, the cholesterol separates in crystals. After the removal of the fat, the residue is treated with anhydrous alcohol, which takes up bilin, bilifellinic acid, and biliverdin. The filtered alcoholic solution is then treated with a solution of chloride of barium, as long as a dark green precipitate falls; and afterwards with baryta water, *guttatum*, as long as it causes any turbidity; it is then filtered, the excess of baryta thrown down by a stream of carbonic acid, the carbonate of baryta removed by filtration, and the solution evaporated to perfect dryness. The residue is dissolved in anhydrous alcohol, all the bases are thrown down from the alcoholic solution by sulphuric acid dissolved in strong spirit, and then, after filtration, the solution is mixed with moist, pure carbonate of lead, and the greater part of the alcohol distilled. The fluid remaining in the retort is removed by filtration from the insoluble portion, the lead removed by sulphuretted hydrogen, and the fluid evaporated. The residue, after being extracted with ether, leaves pure bilin mixed with a certain amount of fellinic and cholinic acids, which must be separated with oxide of lead. We then obtain pure bilin and bilifellinic acid combined with oxide of lead.

An accurate quantitative determination of the most important ingredients of the bile, although difficult, is by no means impracticable. It is, however, very uncertain whether the result of the analysis would afford any insight into the true character of that changeable secretion. From the latest researches of Berzelius, it appears that the bilin is so unstable a compound, that it is hardly possible to obtain bile in the condition in which it is secreted by the liver, or as it exists in the gall-bladder; for when bile is left to itself, and much more when it is acted on by heat and other more or less energetic agents, the bilin undergoes a series of metamorphoses by which fellinic, cholinic, and very probably also cholic and fellanic acids are produced. The biliary secretion, as it exists in the liver, may be regarded as pure bilin mixed with biliverdin and fats; the bilin probably commences its metamorphoses in the gall-bladder, and continues them in its passage onwards into the intestinal canal. If fellinic and cholinic acids are formed in the gall-bladder, then the presence of the two bilifellinic acids in fresh bile may be at once assumed, since they are only to be regarded as combinations of the former with different proportions of bilin. It is not by any means probable that cholic acid exists in fresh bile, and the presence of dyslysin and taurin may be positively denied; consequently, the biliary resin, the mixture of fellinic and cholinic acids and dyslysin does not pre-exist in the bile.

Berzelius and Thénard have made quantitative analyses of healthy human bile: they found, in 1000 parts:

	Berzelius.	Thénard.
Water	- 907·4	Water
Bilin, fellinic acid, &c.	- 80·0	Yellow and very bitter resin
Mucus dissolved in a free alkali	- 3·0	Brown pigment and mucus

Free alkali and the ordinary salts	9.6	Albumen	39.2
		Soda holding the resin in solution	5.1
		Salts of potash and soda, and peroxide of iron	4.1

According to Gmelin and Tiedemann, human bile contains biliary sugar, brown pigment, a little biliary resin, cholesterin, ptyalin, mucus, oleic acid, and salts.

[In the year 1837, Demarçay announced that the bile consisted essentially of an organic acid combined with soda. He termed this acid *choleic*, and obtained it in the following manner: Bile from which the mucus had been precipitated by alcohol was evaporated on the water-bath, and ten parts of the dried residue were dissolved in 100 of water, to which ten of hydrochloric acid had been added. Allowing evaporation at a moderate temperature to proceed, it was observed that a dark green oil collected on the surface, while, at the same time, the fluid became turbid. On removing the oil, and allowing the fluid to rest for some time, it gradually became clear, with the precipitation of a green deposit. This dark green bitter precipitate is Demarçay's choleic acid, and is regarded by him as constituting nine tenths of the solid constituents of the bile. It is still mixed with margaric acid, cholesterin, pigment, &c. After the removal of these impurities, it is described by Demarçay as a yellow, spongy, pulverulent matter, which rapidly absorbs oxygen from the atmosphere; very bitter, slightly soluble in ether, soluble in water, and very soluble in alcohol. Its solutions have an acid reaction, decompose carbonates, and form a peculiar class of salts with bases from which the choleic acid may be removed by acetic acid. Its composition is represented by the formula $C_{44}H_{50}NO_{12}$. The choleate of soda obtained by adding an alcoholic solution of soda to an alcoholic solution of choleic acid till there is an alkaline reaction, and then passing a current of carbonic acid through it to remove the excess of soda, possesses all the characters of bile; it yields, on evaporation, a brown resinous mass, and is soluble in water and in alcohol.

When choleic acid is boiled with hydrochloric acid, it yields ammonia, taurin,¹ and choloidic acid; the latter being insoluble, is deposited. (Compare this with page 50.) Choloidic acid is solid, fusible, of a yellow colour, and bitter taste, insoluble in water, and soluble in alcohol. It combines with bases, neutralizing them, and forming salts which are soluble in alcohol. It contains no nitrogen, and its formula is $C_{72}H_{50}O_{12}$.

Dr. Kemp has communicated some experiments relative to the bile, tending to show that it is principally composed of a mere simple solution of a salt of soda, the acid which differs from the choleic acid of Demarçay in several respects; he terms it bilic acid.

¹ It has been recently asserted by Redtenbacher that taurin contains 26% of sulphur. Hence the formula C_4H_8NO (see 49) fails to represent its true composition.

Liebig has published a memoir based on Kemp's experiments, in which he arrives at very similar conclusions, but regards bilic acid as identical with the choleic acid of Demarçay and the bilifellinic acid of Berzelius.

Theyer and Schlosser have subsequently published an account of some new researches on the bile which were made in the Giesessen laboratory, and confirm the accuracy of Liebig's previous conclusions.

In a recent essay on the bile, by Platner,¹ it is shown that the bilic acid and acid bilate of soda may be procured in a crystalline state. In a subsequent communication by the same chemist, after correcting certain errors in his first paper, he proceeds to show that two distinct substances are met with in perfectly fresh bile: "I have been able," he observes, "to cause bile, which was evaporated in a water-bath, and freed from mucus and the greater part of its salts by repeated solution in alcohol, to crystallize immediately. For this purpose nothing further is necessary than to add ether repeatedly to as strong an alcoholic solution of the bile as possible, and then to set it aside in a cool place. The principal and most important constituent of the bile then crystallizes, in the same manner as in my former experiments; but $\frac{1}{8}$ — $\frac{1}{4}$ of the bile used does not crystallize, but remains as yellowish-brown syrup. I have not been able to succeed in separating this in any manner from the crystals; consequently, I can say nothing more concerning its nature. It is, however, evidently a different substance from the principal constituent of the bile, possibly a product of its decomposition. The decomposition of the bile begins even in the organism, and it is impossible to examine fresh bile which is not partly decomposed. The brown liquid appears to consist principally of biliary colouring matter. I must, however, remark that the crystals have also a slightly yellow tint. The principal constituent of bile is a compound of soda with a peculiar organic body, and this compound may be immediately procured from the bile without its undergoing any important alteration. Liebig called this compound bilate of soda; I have denominated it choline-soda. It does not appear to me sufficiently proved that the principal organic constituent of bile is positively an acid. It is possible that, like albumen, it may combine with acids as well as with bases. The most recent examinations of the bile by Berzelius would then be partly true. Further experiments must decide this. These, however, are peculiarly difficult, because, in separating the bile from soda, an acid body may undoubtedly be formed. From the above observation, it is further evident that the formula advanced by Liebig for bilic acid must be incorrect; for Kemp, Theyer, and Schlosser have not analyzed the essential biliary ingredient in a perfectly pure state, but have always at the same time included the brown syrup.]

¹ Müller's Archiv. No. 2, 1844.

Morbid Bile.

Our knowledge of the changes that the bile undergoes in disease is still very superficial.

In persons suffering from dropsy, the bile is stated by Forget to be thinner, and, in persons with diseased liver, thicker, than in the normal state. I examined the contents of the gall-bladder of the woman with icterus, referred to in p. 269. I only obtained a small quantity of viscid, dirty yellow fluid, from which alcohol precipitated mucus and albumen. The portion soluble in alcohol yielded, after evaporation, a small quantity of a viscid substance with a sweet rather than a bitter taste. Bizio¹ has analyzed a remarkable specimen of bile taken from the gall-bladder of a man who died in a jaundiced condition. It was a fluid of a dark-red colour, thick, of a nauseous but not bitter taste, with an odour of putrid fish, and holding in suspension red and black particles. It contained fatty oil, 3.972; stearin, 8.613; green resin, 2.030; a yellow, non-nitrogenous, hard substance, soluble in alkalies, in cold hydrochloric acid, and in alcohol, 1.937; erythrogen, 4.157; dissolved haematin, 3.148; a gummy-saccharine extract with colouring matter, 1.978; soluble albumen, 7.282; fibrin, 11.348; phosphate of soda, 1.340; chloride of sodium, 0.984; phosphate of lime, 1.320; peroxide of iron, 0.532; water, 51.232.

[Scherer² analyzed the bile of a man who died in a state of icterus. It was a thick fluid of a blackish green colour, and exhibited under the microscope a large number of pigment-cells. It contained in 1000 parts:

Water	-	-	-	859.6
Solid constituents	-	-	-	140.4
Bilin	-	-	-	48.6
Bilifellinic acid	-	-	-	30.5
Fat	-	-	-	8.6
Bile-pigment	-	-	-	44.3
Salts	-	-	-	8.0

Not a trace of cholesterin could be discovered in this bile, which Scherer regards as singular, although, according to Berzelius, it amounts to only .0001% of healthy bile, (in the ox,) a quantity easily overlooked. The bile-pigment³ in healthy bile is imponderable; its amount in this case, as well as that of the solid constituents generally, is enormous.]

Chevallier⁴ found that the bile of a man with scirrhoue pancreas, who died jaundiced, was of a pale greenish yellow colour, evolved a

¹ Brugnatelli Giorn. di Fisica, vol. xv. p. 455.

² Untersuchungen, &c., p. 103.

³ [Scherer has recently investigated the composition and properties of biliary colouring matter. A notice of his researches may be found in my Report on the Progress of Chemistry in "The Half-yearly Abstract of the Medical Sciences," vol. i. 1845.]

⁴ Jour. de Chim. Méd., vol. ii. p. 461.

putrid odour, had an alkaline reaction, and a faint, slightly saline taste: it contained a yellow, semi-crystalline fat, green resinous matter, ptyalin, osmazome, soluble albumen, hydrosulphate of ammonia, and phosphate, sulphate, and hydrochlorate of soda. Chevallier found that the bile of a woman who died from pulmonary phthisis was of a brownish yellow colour, and yielded 2% of dried residue, of which 0·83 was biliary sugar. According to Chevreul, the bile in cases of phthisis contains very little fat. The bile of a woman who died from the effects of syphilis is described by Chevallier as of a dark green colour; it yielded 20—30% of dried residue, of which one third, or 0·94, was biliary sugar, with resinous and yellow matter.

Phœbus¹ found, that in persons who died from cholera, the gall-bladder was usually tolerably full, (sometimes to an excess,) and that the bile was rather dark-coloured. According to Herrmann, the bile in cholera contains an excess of resin.

In cases of fatty degeneration of the liver, there is, according to Thénard, a diminution of the biliary resin, and the bile appears as a mere albuminous fluid, and by the time that the liver contains five-sixths of its weight of fat, the bile loses all its original characters.

Lehmann² states that the bile of a dropsical boy developed a large amount of hydrosulphate of ammonia, a circumstance, which in other cases, did not occur even when the bile had been kept for some days.

Bile of Animals.

The bile of animals has been examined by Berzelius, Gmelin, Thénard, myself and other chemists.

[According to the latest observations of Berzelius, filtered ox-gall, when evaporated to dryness at a temperature of 266° gives off 928·38 parts of water, and leaves 71·62 of solid residue, consisting of—

Mucus	2310
Extractive matter insoluble in alcohol, with alkaline sulphates and phosphates	4·334
Chloride of sodium, lactate of soda, and extractive matter soluble in alcohol	15·000
Bilin and cholepyrrhin	50·000
Cholesterin	·001

According to Enderlin,³ the following salts occur in the bile of the ox:

Cholate (or bilate) of soda,
Tribasic phosphate of soda,
Alkaline sulphates,
Chlorides of sodium and potassium,
Phosphate of lime,
Phosphate of magnesia,
Phosphate of peroxide of iron, and occasionally
Sulphate of lime.

The bile of the ox and of the swine has likewise been analyzed

¹ Cholera Archiv. vol. i. p. 399.

² Summarium, vol. xii. 1839.

³ Annalen der Chemie und Pharmacie, 1844.

by Thénard, and the bile of the dog by Gmelin, but the descriptions are of so vague a character as to be of little or no use. The same objection applies to their examination of the bile of various birds.]

In the bile of the *Python bivittatus* Berzelius found bilin (as in the mammalia,) a small quantity of bilifellinic acid, bile-pigment the same as in other classes of animals, a little crystalline biliary matter precipitable by carbonate of potash, similar to that which occurs in the bile of fishes, ptyalin or a substance resembling it, a peculiar animal matter, soluble only in boiling water, fatty acids, and the ordinary salts. The bile of the *Coluber natrix* is described by Gmelin as of a grass-green colour, transparent, perfectly fluid, and passing through the ordinary change of colour (blue, red, and yellow) on the addition of nitric acid.

The bile of the *Rana esculenta* and *R. temporaria* is very fluid, of a pale green colour, and yields the ordinary series of tests with nitric acid. The bile of the water frog leaves a somewhat crystalline residue on evaporation; the bile of the grass-frog has a sweetish taste, and is less bitter than fish bile.

The bile of the *Cyprinus leuciscus* is described by Gmelin as green, transparent, and fluid, communicating a sweet and afterwards a very bitter taste to the gustatory organs, neutral in its reaction, affected, as to its colour, by nitric acid like other bile, and coagulating immediately on the addition of potash into a greenish white granular mass, becoming covered, on evaporation, with an almost colourless crystalline film, and yielding 14·3% of a dark green, transparent, crystalline residue.

The bile of the *Cyprinus barbus* is similar to that of *C. leuciscus* in its physical characters, and yields 19·3% of a dark green crystalline residue.

The solid residue of the bile of the *Salmo furio* and *Esox lucius* is stated to be non-crystalline.

On the Action of the Bile in the process of Digestion.

We are as ignorant of the action of the bile on the chemical changes that the food undergoes in the intestinal canal and in the process of chylification, as of the exact influence of the saliva or of the pancreatic juice. Experiments, with the view of deciding this point, have been instituted by Brodie and by Tiedemann and Gmelin, and the conclusions to which they lead, are, that the bile does not exert any material influence upon digestion and chylification. Assuming that these experiments were correctly performed, the bile must be regarded as a mere excretion, whose removal from the organism is as necessary for the preservation of the normal constitution of the blood as the removal of carbonic acid, urea, &c.

Tiedemann and Gmelin state as the results of their observations on animals, in which the flow of bile into the intestine was prevented:

1st, that digestion (as had been stated by Brodie) proceeds just as perfectly as when the supply of bile is not hindered; 2d, that the contents of the small intestine, cæcum, and large intestine, after the application of a ligature to the ductus communis choledochus, do not differ in any essential degree from their ordinary state; and 3d, that the bile plays no essential part in the formation of chyle.

Notwithstanding these general conclusions, they found that the chyle of dogs, in whom the ductus communis choled. was tied, was perfectly clear, whilst in the natural state it is white and turbid in consequence of the fat held in suspension; a difference not to be passed over as altogether unimportant. Another undeniable effect of the bile in chylification consists in the neutralization of the free acid of the chyme by the alkali that is associated in so unstable a manner with the biliary secretion, in consequence of which the bilin gradually begins to undergo certain changes, but whether of the same nature as in the laboratory of the chemist it is impossible to decide.

[That the bile is not merely an excrementitious fluid, intended to remove effete matter from the blood, but that it is a secretion essential to the animal economy, was rendered almost certain by the experiments of Berzelius, Theyer, and Schlosser, which showed that the human faæces contained much too small a quantity of a substance resembling bile to justify the idea that it is evacuated in this manner. A further proof that the bile is absorbed and not excreted, is afforded by an examination made by Enderlin, of the ash yielded by the contents of the different portions of the intestinal canal of a hare. He found that the ash from the contents of the duodenum alone effervesced on the addition of an acid, thus showing that the choleate of soda (which yields the carbonate on incineration,) is absorbed before reaching the jejunum. Schwann has recently established this opinion beyond a doubt, by a series of well-devised experiments on dogs. He tied the ductus communis choledochus, and at the same time formed a fistulous opening in the gall-bladder, by which the bile escaped externally. His most important conclusions are, 1st, That when the bile does not get into the bowel, its absence is generally perceptible in dogs, about the third day, by a marked diminution in weight; and, 2dly, That unless the channel for the conveyance of bile to the duodenum is re-established, symptoms of deficient nutrition, wasting, debility, &c., ensue, and death is the ultimate consequence.]

If the bilin becomes decomposed in the intestinal canal into various constituents, through the influence of the acid chyme, then a wide field of investigation is open to us respecting the function of the biliary secretion in relation to chylification. No explanation has yet been afforded of the discrepancy in the amount of albumen contained in the chyme absorbed by the intestinal villi, and in the chyle discharged by the absorbents, (even without passing through the

mesenteric glands.) May it not happen that a constituent of the bile acts on some hitherto ill-defined protein-compound of the chyme, and converts it into the form known as uncoagulated albumen?

ON THE GASTRIC JUICE, DIGESTION, AND THE CHYME.

Gastric Juice.

The gastric juice has been examined by numerous chemists, in consequence of the importance attributed to it in the process of digestion. There have been found in it free acids, a considerable amount of salts, and certain indefinite animal substances, which were known at the period to which we refer as osmazome or salivary matter. Experiments on artificial digestion have thrown much light on the nature of the gastric juice. Eberle¹ proved that an artificially-formed gastric juice does not thoroughly dissolve food, unless a small quantity of gastric mucus, or a portion of the mucous membrane of the stomach be added to it. On the strength of this discovery, Müller and Schwann² instituted a series of experiments, from which Schwann was led to conclude that the gastric juice contains a peculiar substance, which, co-operating with an acid, possesses the property of rapidly dissolving substances insoluble in mere water, or in a mixture of extractive matters, salts, and a little acid, as for instance, fibrin, coagulated albumen or casein. To this somewhat problematic substance he gave the name of *pepsin*: Wassmann³ and Pappenheim⁴ have endeavoured to isolate it. (See p. 30.)

Prout⁵ has shown that the free acid of the gastric juice is muriatic acid. Gmelin and Tiedemann⁶ have found it associated with acetic acid, and in the gastric juice of horses, with butyric acid: there is no doubt that lactic acid is likewise contained in it. From the researches of the latter chemists, which are the most perfect that we possess on the subject, it appears that in addition to the free acids, the gastric juice contains mucus, and occasionally (in horses) a very small quantity of albumen, extractive and salivary matter, and that the ash consists of alkaline muriates and sulphates, a little phosphate and sulphate of lime, chloride of calcium, magnesia, and peroxide of iron.

The gastric juice collected from the empty stomach, although mixed with mucus, was tolerably clear; it was neutral, of a yellow colour, a saline taste, and on evaporation left only 2% of solid constituents. Gastric juice obtained by irritating the stomach with pebbles was acid, viscid, and of a pale brown colour. Hünefeld does not believe that there is any free hydrochloric acid in gastric juice.

¹ Physiologie der Verdauung. Würzburg, 1834.

² Über die künstliche Verdauung des geronnen Eiweisses, Müller's Archiv. 1836.

³ De Digestione nonnulla. Diss. inaug. Berol. 1839.

⁴ Zur Kenntniß der Verdauung. Breslau, 1839.

⁵ Philos. Transactions, 1824, p. 45.

⁶ Die Verdauung nach Versuchen, p. 150.

Berzelius analyzed gastric juice collected by Beaumont from a young man with a fistulous opening into the stomach. It had been kept for five months before Berzelius received it, and was therefore totally unfit for the purpose of analysis. In that condition it was clear, yellow, devoid of odour, reddened litmus paper in a decided manner, and left a solid residue of 1·269%, consisting principally of crystals of chloride of sodium, in the interstices of which was a brown extractive matter, which, on exposure to the air, resolved itself into a dark brown thick syrup. Its quantity was too small to admit of its being accurately examined, but it was proved to contain lime and a proto-salt of iron. Beaumont describes human gastric juice as a clear, inodorous, saline, and very acid fluid, which effervesces on the addition of alkalies. Dunglison detected in it free hydrochloric acid, an animal substance soluble in cold but not in hot water, and acetic, phosphoric, and hydrochloric acids, in combination with potash, soda, lime, and magnesia.

The gastric juice of a horse, collected by irritating its empty stomach with pebbles, was found by Gmelin to contain:

Water	-	-	-	-	-	984.00
Solid residue	-	-	-	-	-	16.00
Organic constituents	-	-	-	-	-	10.62
Salts soluble in water	-	-	-	-	-	5.02
Salts insoluble in water	-	-	-	-	-	0.46

[Braconnot has examined the gastric juice collected by means of sponges from the stomachs of dogs, but his results are not very definitely given.]

Hence it appears that the principal constituents of the acid gastric juice are pepsin; a substance not yet carefully examined, but bearing a close resemblance to extract of flesh; an unexamined substance resembling salivary matter; free acids, especially muriatic acid; mucus; sometimes a little albumen; salts, especially alkaline chlorides, muriate of ammonia, (according to Hünefeld,) and a small quantity of earthy salts.

M. Blondlot has recently published a treatise on digestion,¹ detailing very numerous experiments made upon dogs, in which fistulous openings into the stomach were maintained for upwards of two years. The gastric juice was obtained in very large quantities. Submitted to distillation, the fluid passing over did not exhibit the slightest acid reaction, whilst the residue in the retort was always strongly acid. Hence he concludes that the acid of the gastric fluid is neither hydrochloric nor acetic acid, since both these are volatile. The gastric fluid of other animals gave the same result on being distilled. When chalk or any other carbonate of lime was added, no effervescence ensued, proving the acid not to be the lactic. M. Blondlot concludes that the acid reaction of healthy gastric juice is owing to the presence

¹ *Traité analytique de la Digestion.* Paris, 1843.

of superphosphate or biphosphate of lime. He adds—1st. That there is no other acid fluid which can remain acid, and fail to decompose carbonate of lime. 2d. That sulphuric acid, added to gastric juice, precipitates an abundance of sulphate of lime, and oxalic acid precipitates oxalate of lime. 3d. Potass, soda, ammonia, and lime water, produce abundant precipitates of neutral phosphate of lime. 4th. That the calcined ash of gastric juice is not deliquescent, dissolves without effervescence in hydrochloric acid, forming chloride of calcium; it therefore contains neutral phosphate of lime, the excess of acid being driven off in the calcination.

M. Blondlot believes that the digestive property of gastric juice depends, not on its obvious chemical constitution, but upon a peculiar organic principle. If exposed to a temperature of 104° to 122° F., or higher, it loses entirely and irrevocably its digestive powers, although to all appearance, and even as to its composition, as made known by analysis, it remains unchanged. With the exclusion of the air, gastric juice may be kept for two years without loss of its activity; but with the free access of air, it putrefies in five or six days, although the chyme which it forms from nitrogenous organic substances may be preserved for two or three months without change. The precipitation of all the lime it contains does not affect its activity, nor are its chlorides indispensable, but whatever acts upon its organic constituents, (heat, strong alcohol, or strong acids,) or which removes them, (such as animal charcoal, chlorine, tannic acid, or acetate of lead,) destroys all its digestive properties.

M. Blondlot also shows—*a*. That coagulated albumen resists the action of the gastric juice only from its compact form. When coagulated in very small particles, as the white of an egg beaten into a froth and poured into boiling water, it is digested as quickly as soft fibrin. *b*. That the action of the stomach in coagulating milk is not due to its digestive principle solely, but to its acid, which acts like lactic acid. *c*. That the effect of the gastric fluid upon bones, whether entire or not, is to disintegrate them slowly, beginning at the surface, and to reduce the earthy matter into a fine chalky powder, but without dissolving or decomposing it. The earthy matter not being dissolved, proves that no hydrochloric acid has acted upon it; it is all discharged with the faeces.

Since the work of M. Blondlot was published, two other French chemists, MM. C. Bernard and C. Barreswil,¹ have made an experimental investigation into the properties of the gastric juice. They start with the assumption that this fluid owes its digestive properties to the union of two principles: 1st, an acid; 2d, a peculiar organic matter destructible by heat. What is the nature of the acid? “The principal fact which has been adduced to prove that the acid reaction is owing to the presence of biphosphate of lime is, that it may be treated with carbonate of lime without effervescence. Our experiments show that this arises from the dilution of the acid, which allows

¹ Journal de Pharmacie, Jan. 1845.

the carbonic acid to be dissolved as it is formed. When, therefore, the gastric juice is concentrated, it causes a considerable effervescence with chalk. Moreover, gastric juice dissolves neutral phosphate of lime, whilst this salt is entirely insoluble in a solution of the biphosphate. On distilling gastric juice, the first distillate exhibits no acid reaction. If a mere trace of acetic acid or acetate of soda is added previous to distillation, it gives no acid reaction; the normal acid is not therefore acetic. This also appeared, at first sight, to prove it could not be hydrochloric acid; but on distilling water rendered slightly acid by hydrochloric acid, nothing passes over at first but pure water, the acid not distilling until the end of the operation. On distilling gastric juice, a neutral limpid liquor passes over, which is not precipitated with nitrate of silver; when about four-fifths has distilled over, the distillate is perceptibly acid, nevertheless, it does not render a solution of nitrate of silver turbid; but at the end, and when only a few drops of the gastric juice remain in the retort, an acid liquid passes over which precipitates salts of silver; this is, doubtless, hydrochloric acid. Does this acid exist free in gastric juice, or has a chloride been decomposed in this operation? When the least trace of oxalic acid is added to gastric juice which we know contains lime, a turbidity is produced from the formation of an insoluble oxalate of lime; but if to water acidified with 2000ths of its amount of hydrochloric acid, and containing chloride of lime, the same reagent be added, no turbidity ensues. This clearly proves that hydrochloric acid exists as a chloride in the gastric juice, and not in a free state.

When concentrated by evaporation, gastric juice is strongly acid, effervesing with chalk, and not losing its acid reaction in the presence of an excess of the chalk. This proves the presence of phosphoric acid. On saturating the acid with lime and oxide of zinc, and filtering the solution, the neutral filtrate contains both zinc and lime, therefore phosphoric acid is not the only free acid in the juice. What is the acid combined with the zinc and lime in the filtered solution? It is one which, as we have seen, passes over at the end of the distillation, and does not precipitate salts of silver. These characters belong to lactic acid. On distilling water slightly acidulated with lactic acid, a small quantity of chloride of sodium being added, we obtain a fluid analogous to gastric juice; first, pure water passes over, then an acid which does not precipitate salts of silver, and the last drops carry over hydrochloric acid. So that it is evident that the presence of hydrochloric acid in the last product of distillation of the gastric juice is owing to the decomposition of the chlorides by lactic acid."

Hydrochloric acid cannot exist in a free state in the presence of a lactate, a phosphate, or an acetate. "We have observed," say the authors, "in the acid of the gastric juice all the characters of lactic acid, as pointed out by M. Pelouze; both give soluble salts of lime, barytes, zinc, and copper, a double salt of copper and lime, deeper in colour than the simple salt, and a salt of lime, soluble in

alcohol, precipitated by ether." From the above facts, MM. Bernard and Barreswil conclude that the acid reaction of the gastric juice is not owing to biphosphate of lime, but arises from a free acid which is not hydrochloric or acetic acid. They have always found lactic acid, with a minute proportion of phosphoric acid, the latter being a product of the reaction of the lactic acid on the phosphates present. In their opinion, lactic acid is a constant production of the stomach. They do not mean to say that the digestive powers of the gastric juice are owing to lactic acid; on the contrary, they think if an acid reaction be indispensable, other acids may supply its place, because among the various salts constantly introduced into the stomach with the food, some will have their acid replaced by the free lactic of the stomach, and the new acid liberated, may supply the place of the normal acid.

In a more recent memoir they enter more fully into the nature of the active organic matter, on the presence of which they believe the digestive power of the gastric juice to depend. It is precipitated and destroyed at a temperature of 190°. One of the most remarkable of its properties is that its digestive powers vary according to the medium in which it is contained. In the gastric juice, which is acid, it dissolves nitrogenous matters, such as fibrin, gluten, and albumen; but exerts no action on baked starch; but if the gastric juice is rendered alkaline by the addition of a little carbonate of soda, it rapidly dissolves the starch, and no longer possesses the power of acting on the nitrogenous matters. As these physiological properties are exactly those of saliva and the pancreatic fluid, it became an interesting point to ascertain if a change in the reaction of these fluids would cause a corresponding variation in their solvent power. This was found to be the case; on acidulating these naturally alkaline fluids, their ordinary mode of action was inverted, and they were enabled to dissolve nitrogenous matters, while their capability of dissolving starch was lost. From numerous and varied experiments they believe that one and the same organic principle (the agent of digestion) exists in the gastric juice, the pancreatic fluid, and the saliva, and that its physiological action varies according to the acid or alkaline nature of the fluid in which it occurs.

M. Melsens¹ has also examined the gastric juice, and denies the accuracy of Blondlot's conclusions.]

The fluid secretion in the crops of birds is stated by Gmelin and Tiedemann to have an acid reaction; and the fluid in the glandular stomach, even when empty, contains free acids, especially muriatic and acetic acids.

Brugnatelli observed that Iceland spar enclosed in tubes is decidedly attacked after remaining for some time in the stomachs of hens and turkeys; and Treviranus noticed that a porcelain basin, in which

¹ Journal de Pharmacie, Jan. 1845.

the chyme of hens had been digested, was corroded, from which he concluded that fluoric acid was present. Tiedemann and Gmelin did not succeed in detecting fluoric acid in the gastric juice of ducks, although they carefully sought for it.

Morbid Gastric Juice.

It is well known that the gastric juice sometimes assumes anomalous characters, but important as such modifications are to practical medicine, little is known with certainty in relation to their true causes, and still less respecting the peculiar influences that morbid gastric juice exercises on chymification and chylification. The question naturally suggests itself, whether morbid changes in the gastric juice may not be the origin of many of the diseases of early childhood. Such changes may originate purely from internal causes (nervous influences,) or from a complication of the above with external influences, such as diet, &c.

The only modifications respecting which we can speak with any degree of certainty are the following: 1st, There may be a considerable excess of free acid; 2dly, There may be a diminution of free acid; and 3dly, The gastric juice may become positively alkaline. In all probability, with these there are associated other changes in the composition of the fluid, producing an injurious effect on the process of digestion; but on this subject we are unable to speak with certainty.

The increased acidity of the gastric juice usually arises from an excess of those acids which exist in it in a normal state, namely, muriatic, acetic, and lactic acid. When there is a tendency to the formation of an excess of acid in the gastric juice, it appears to be developed from the food. Muriatic acid is principally developed from animal food; acetic and lactic acids from vegetable and especially saccharine food, such as acid bread, beer, and wine; and the fatty acids from an excessive use of fatty matters. An excessive acidity of the gastric juice is frequently observed in cases of gastritis serosa, and of scrofula and rickets associated with disease of the spleen. In gout, podagra, and nettlerash, the gastric juice contains, according to Stark¹, phosphoric and uric acids; the presence of the latter acid must however be regarded as very problematical.

The cases in which the gastric juice exhibits a positively alkaline reaction are comparatively rare. This deviation from the normal condition arises chiefly from the use of salted or putrid food and drink containing basic salts, from prolonged fasting, and especially from care and anxiety (Stark.)

The experiments of Purkinje and Pappenheim show that when the gastric juice is mixed with bile, its digestive powers are diminished.

Our knowledge of the uses of the gastric juice in the process of digestion, is much clearer than that of the other fluids already de-

¹ Allgem. Pathologie, p. 848.

scribed, as the saliva, pancreatic juice, and bile. We know that alimentary matters insoluble in mere water are readily dissolved by the pepsin of the gastric juice combined with a little free dilute acid, and that some of these substances become chemically changed during the process of solution.

The intestinal fluid.

The small intestines, when empty and not irritated, secrete an almost neutral, very viscid fluid, but during digestion, or when irritated, the secretion becomes decidedly acid. We cannot examine this fluid in a state of purity, but it is most probable that in its constitution it is similar to the gastric juice, and that it possesses the property of acting on those substances which have escaped the solvent power of that fluid. According to Tiedemann and Gmelin it contains a large quantity of albumen; this is, however, most likely due to the pancreatic fluid which becomes mixed with it. It must also be more or less mixed with the biliary secretion.

On the process of Digestion, and the Chyme.

By the process of digestion we understand the solution and the modifications that the food undergoes in the stomach and adjoining portion of the intestinal canal, together with the absorption and metamorphosis of the nutrient fluid (chyme) contained in the reduced pulpy mass of the food, till it becomes perfect chyle.

The subject of digestion has attracted much attention for the last seventy years, but unfortunately the results that have been obtained are by no means proportionate to the time and labour involved in the experiments instituted in relation to this department of physiology.

The discovery and isolation of pepsin forms a new epoch in the chemical history of digestion. It is now in our power to institute experiments on artificial digestion with every prospect of success; we can examine the new products that are developed, and we shall be thus led to the true understanding of the formation of chyle, which as we know is always tolerably constant in its composition, although evolved from the most diverse species of nutriment.

Previously to commencing such researches, it would be requisite to study and examine the pepsin obtained from different classes of animals; for it is very possible, as Berzelius suggests, that it may be a mixture of various substances, differing in different classes of animals. On this account, various simple natural substances, after the addition of a due quantity of acid (which must be determined experimentally,) should be artificially digested with the different sorts of pepsin, and the products, both soluble and insoluble, carefully analyzed. Such terms as osmazome, salivary matter, &c. must be rejected. The researches of Berzelius and myself have opened the way for an exact and separate determination of the extractive matters and ptyalin.

We should then be enabled to see what real connexion there is between the substances resembling extract of flesh which are produced in artificial digestion, and those that are actually obtained from flesh itself.

Our knowledge of the changes that the different elements of food undergo in the process of digestion is at present very limited; it is confined to the following leading points.

1. Albumen is dissolved and chemically changed. This observation was made by Eberle, and has been confirmed by Müller, Schwann¹, and others. The digested albumen no longer coagulates at the boiling point; it is stated to have been changed into osmazome and salivary matter, (a vague statement requiring further proof,) and according to Schwann, into a third albuminous principle, which is thrown down by carbonate of soda, and in that condition is insoluble in water and spirit, soluble in muriatic and acetic acids, and not precipitable by acetate of lead or alcohol, but copiously by nitric acid and bichloride of mercury, and partially by ferrocyanide of potassium and tannic acid.

2. Coagulated casein is partially converted by artificial digestion into albumen; soluble casein becomes coagulated when submitted to the action of a solution of sugar of milk and pepsin, but not when acted on by the pepsin alone.

3. Fibrin is rapidly dissolved, and, from the experiments of Tiedemann and Gmelin, appears to be partially converted into albumen.

4. Glutin becomes so changed by artificial digestion, that it loses its property of gelatinizing, and can no longer be precipitated by chlorine.

5. Sugar of milk, when submitted for a sufficient time to the action of pepsin, becomes completely converted into lactic acid. This fact has been established by Fremy and myself.

6. Starch is partially converted into sugar. (Tiedemann and Gmelin.)

7. The fluid found in the stomach of a horse, fed with oats, contained butyric acid, a resin, a substance resembling extract of flesh, salivary matter, and albumen.

From recent experiments on digestion, we know that alimentary substances are dissolved as rapidly in an artificial digestive fluid, consisting of pepsin and properly diluted muriatic acid, as they are in the gastric juice itself. Hence we are justified in the conclusion that pepsin, the free acid, and a suitable temperature, are the principal agents in gastric digestion, and that the motions of the stomach are chiefly with the view of promoting the due admixture of the food with the secreted fluid, and of propelling it towards the pylorus, through which it must pass in order to enter the duodenum. It is impossible to state with certainty whether the pepsin and free acids

¹ Müller's Archiv. 1836, p. 63.

dissolve and modify the food through a catalytic influence, or whether they enter into any chemical combination with it, the products of these combinations being the dissolved and changed matter. If, however, the conversion of sugar of milk into lactic acid is explained by the catalytic action of the pepsin, we may fairly conclude that the pepsin exerts a similar influence on other substances, if no facts to the contrary present themselves. Hünefeld is inclined to attribute considerable influence in digestion to the ammoniacal salts of the gastric juice, in consequence of having observed that under certain conditions fibrin is readily soluble in the muriate or lactate of ammonia, especially when free lactic acid is also present.

The various articles of food are dissolved in the process of digestion with different degrees of facility. Those which approximate most closely to the constituents of the chyle, obviously require the least modification, as, for instance, the fluid albumen and yolk of egg, fibrin, boiled albumen, muscular flesh, casein, and the protein-compounds generally. Certain substances are not at all digestible, as, for instance, woody fibre, husks of fruit, horn, hair, &c. We always observe a relation between the degree of the changes requisite for the assimilation of different sorts of nutriment, and the complexity of the digestive apparatus. Hence, in the carnivora, the intestinal canal is much shorter and simpler than in the herbivora.

In the ruminantia, the first two stomachs do not secrete an acid, true gastric juice, such as occurs in the stomachs of men and carnivora, but a thin yellow saline fluid containing enough alkaline carbonates to produce a marked effervescence on the addition of an acid. Their nutriment (grass, hay, &c.,) after being chewed and mixed with saliva, is first received into these stomachs, where it is soaked in the alkaline fluid, which dissolves and takes up vegetable albumen and glutin. The fluid gradually passes onwards into the third stomach, while the insoluble portion returns to the mouth for a second mastication. The fluid obtained by pressure from the contents of the first stomach (the paunch) contains, according to Tiedemann and Gmelin, carbonic acid and sulphuretted hydrogen, albumen in combination with soda, carbonate of ammonia, and certain animal matters, one of which is volatile and assumes a red tint on the addition of muriatic acid. In addition to carbonic acid and sulphuretted hydrogen gases, the first two stomachs occasionally develop (especially after the use of fresh clover) an extraordinary quantity of carburetted hydrogen. The third stomach secretes an acid fluid, and in the fourth stomach the acidity is much more marked, the substances dissolved by the alkali being first precipitated and then redissolved in the excess of acid. Finally, chyme is produced, said to be analogous to that which is formed in the stomachs of men and carnivora.

In birds the food is first moistened in the crop with a faintly acid fluid; from thence it passes into the proventriculus, where it meets

with a peculiar and very acid fluid, and it finally reaches the muscular stomach, which effects its thorough trituration.

On leaving the stomach, the food enters the small intestine, where it becomes mixed with the pancreatic juice and the bile. Here it commences to be absorbed by the intestinal villi; moreover, it is here mixed with the intestinal secretion, and it is probable that the digestion, not entirely accomplished in the stomach, is here perfected.

There are many points connected with the process of digestion which have not been hitherto explained. We may especially instance the conversion of chyme into chyle. It is very difficult to understand the source of the large quantity of albumen found in the chyle, even before it has passed the mesenteric glands, and just after its absorption by the intestinal villi.

An experiment made by Tiedemann and Gmelin on the chyme and the chyle of a horse fed with oats, will place the difference clearly before the reader.

a denotes the fluid expressed from the thick, pulpy, acid contents of the stomach. It was of a brownish yellow colour, turbid, became darker on exposure to the air, and much more turbid on boiling, and on the addition of bichloride of mercury. *b* is the brownish yellow fluid from the duodenum. *c* is the brownish yellow fluid obtained from the central portion of the small intestine, mixed with mucous flocculi and with a tough albuminous substance, apparently resembling salivary matter. *d* is the brownish yellow fluid from the lower part of the small intestine. *e* is chyle from the absorbents before its entrance into the mesenteric glands. *f* is chyle from the absorbents after its passage through them: and *g* is chyle from the thoracic duct.

We shall omit the amount of water in these various fluids, and merely compare the composition of their solid residue.

1000 parts of solid residue contained:

	<i>a.</i>	<i>b.</i>	<i>c.</i>	<i>d.</i>	<i>e.</i>	<i>f.</i>	<i>g.</i>
1. Resinous matter, with an acid soluble in ether	1.56	0.79	0.25	0.15			
2. Resinous matter soluble in anhydrous alcohol, alcohol-extract, and salts soluble in spirit	61.56	44.61	67.25	77.60	67.50	42.24	30.44
3. Spirit-extract, probably gummy matters and salts	25.26	10.80	5.08		7.10		
4. Insoluble brown matter		0.66	9.14				
5. Brown nitrogenous matter, soluble only in water	16.32	12.44	7.40	2.50	2.17	3.11	
6. Albumen, oxydized extractive matter, and phosphate of lime	11.00	7.11	5.03	3.10	27.56	49.82	63.98

The numbers in 2, under *b*, *c*, and *d*, refer only to the extractive matters and salts soluble in alcohol, while those under *e*, *f*, and *g* refer not merely to them but also to the fat, the relative proportions of which may be seen in the analyses 4, 5, and 6, of the chyle, in page 291. The numbers in 6, under *e*, *f*, and *g*, indicate the amount of pure albumen in the chyle, whilst under *b*, *c*, and *d* extractive

matter and phosphate of lime are included. It is to the two lines 2 and 6 of the above table that I wish especially to direct attention. The chyme *b*, *c*, and *d* differs from the chyle, by a deficiency of fat in the former, and by an excess of albumen in the latter. If the fat is really contained in the chyme, which we cannot doubt that it is, in what state of combination can it occur so as to escape detection? Does the chyme contain fatty acids, combined with the alkalies (soaps,) and the chyle, ordinary fat? The chyme contains an extraordinarily large amount of substances soluble in alcohol, whose place in the chyle seems to be supplied by albumen; may we not endeavour to clear up this difficulty by supposing that some still unknown protein-compound, soluble in alcohol, has been converted into albumen? If the chyme contains so small a quantity of pre-existing protein-compounds, as the above analyses *b*, *c*, *d* teach us, we must assume that their extraordinary increase in the chyle of the absorbents and of the thoracic duct, must be at least in part due to the influence of the lymphatic glands and vessels, and therefore either directly or indirectly to the blood. But, in opposition to this view, we may remark that it is impossible to conceive that the blood can impart that identical quality to the chyle which renders that fluid the means of supplying nutriment to the blood, and of imparting to it the carboniferous and nitrogenous materials requisite to supply the place of those that have been removed from the body in consequence of waste of tissue. If, however, we bear in mind that the mesenteric veins absorb a fluid from the chyme different from that which is taken up by the lymphatics, we may then perhaps account for the discrepancy between the chemical composition of the chyme and the chyle, by the assumption of a 'vis electiva' residing in the absorbent vessels of these two systems; for the lymphatics absorb and carry off a fluid abounding in protein and nitrogenous compounds, while the venous system takes up an excess of the compounds of carbon and hydrogen; and since the absorbents of the lymphatic system in the small intestines must have taken up a very albuminous chyle, the chyme examined by Gmelin may on that account have been poor in coagulable albumen, and in the same manner the gradual decrease of the albumen in the chyle, as the large intestine was approached, would be accounted for.

Diseased digestion.

It is by no means rare to meet with an excessive formation of acid both in the stomach and the intestines, especially in children. Acid eructations, a sour smell from the mouth, and frequent green stools, afford indications of a morbid digestion, which doubtless originates in too acid a condition of the gastric and intestinal fluids, and on the consequent rapid production of lactic and acetic acids from vegetables and milk. I have observed that the faeces of a child at the breast, suffering from improper digestion, consisted of a large quantity of coagulated casein, and a very acid, greenish, whey-like fluid, with nume-

rous oil-vesicles on its surface. The fat was isolated and contained a large amount of the fatty acids.

A copious secretion of gas is a frequent consequence of diseased digestion. This gas is not a mere mixture of carbonic acid and nitrogen with a little hydrogen (the ordinary gases) but also contains a considerable amount of sulphuretted hydrogen, and, in all probability, phosphoretted hydrogen and carburetted hydrogen.

There can be no doubt that there are anomalies in the process of chylification, in consequence of which an unsuitable chyle is prepared and conveyed to the blood, modified both in its quality and its quantity; but with respect to the particulars of these anomalies we are still perfectly in the dark.

CHAPTER IV.

MILK.

THE milk is a white, fatty, and rather thick fluid, which is secreted by the female breasts during pregnancy and after delivery. A metastatic or vicarious secretion of milk from the skin, the navel, the groin, the stomach, the intestines, the mucous surface of the genital organs, or the axilla, is by no means rare: it has also been observed in the breasts of men.

General physico-chemical characters of the milk.

Perfectly fresh milk has always a decidedly alkaline reaction, and it retains this property for a longer or shorter time: the milk of women retains its alkaline reaction longer than that of cows; and the milk of healthy women longer than that of invalids.

On examining the milk under the microscope we perceive a great number of fat-vesicles of very different sizes swimming in a clear fluid, and occasionally epithelium-cells. From repeated comparisons I have found that the fat-vesicles in the milk of woman are generally rather larger than those in the milk of the cow. In addition to these fat-vesicles, we observe, under certain circumstances, other microscopic objects, of which I shall treat subsequently.¹ The fat-vesicles have, as Raspail declared, a solid envelope, a point which has been confirmed beyond dispute by Henle and myself. Raspail considers that it is composed of coagulated albumen; it is, however, more than probable that it consists of coagulated casein. Henle² has shown that this capsule may be dissolved by acetic acid, and that butter then issues from it; it is probable, however, that this fluid fat becomes enclosed in a new envelope, for Ascherson³ has observed that a mem-

¹ See Pl. 2, fig. 13,* A. B.

² Froriep's Notizen, 1839, No. 449.

³ Über die Hautdrüsen der Frösche und über die Bedeutung der Fettstoffe, Müller's Archiv. 1840.

brane immediately forms around every drop of fat that is brought in contact with a solution of albumen; and I have found that fat shaken with a caseous substance (crystallin) in a state of solution, causes a partial coagulation by the formation of such membranes or capsules. I have shown that when woman's milk is evaporated, and the residue reduced to a fine powder, and extracted with ether (which takes up the butter,) there are left the capsules of the fat-vesicles, which, when mixed with water, and placed on the object-stage, may be observed with the microscope.

Milk is materially affected by a large number of substances, especially by those that precipitate its casein. The addition of any of these substances causes it to coagulate, that is to say, the casein becomes insoluble and encloses the butter, and thus produces the separation of a whey-like fluid from the caseous mass. A precipitation of this nature is brought about by alcohol which at the same time takes up a very small quantity of fat: when milk is shaken with ether, no precipitation of casein ensues, but the milk becomes rather clearer, and the ether is found to contain fat, but only a small portion of all that is contained in the milk. When milk is left to itself for a considerable time, it coagulates, in consequence of the conversion of a portion of its sugar into lactic acid: this change often takes place very rapidly in cow's milk, and generally more quickly than in woman's milk. If the milk is allowed to remain still longer exposed to an ordinary temperature, the surface becomes covered with peculiar forms of mould, and, under certain conditions which are not accurately known, particular species of infusoria are developed. These infusoria are the cause of a blue or yellow colouring matter, which is especially distributed over the surface, a phenomenon that has long been observed, and which has recently been carefully investigated by Fuchs.

Rennet likewise precipitates the casein apparently by a catalytic action on the sugar of milk, by which it is converted into lactic acid; hence the precipitation is hindered by the addition of an alkali, and, as Herberger has observed, does not occur in milk which abounds in alkaline salts.

The solid constituents of the milk vary from about 9 to 35% ; the specific gravity usually lies between 1028 and 1042.

SPECIAL CHEMISTRY OF THE MILK.

Constituents of the Milk, and methods of separating them.

The following substances are contained in a state of solution in healthy milk: casein, fat (including olein, stearin, butyrin, caproin, and caprin,) sugar of milk, extractive matters, and salts. The salts are the chlorides of sodium and potassium: lactates of potash, soda, probably of ammonia, of lime, and magnesia; phosphates of potash, soda, lime, and magnesia; and traces of phosphate of peroxide of iron.

The plans that were formerly proposed for the analysis of milk could not give satisfactory results. For instance, the fatty portion which collects on the surface (the cream) was analyzed separately from the poorer fluid beneath it; by this means, then, were obtained accurate estimates of two separate portions, but not of the milk collectively.

The course adopted by the French chemists, was to evaporate the milk, to take up the butter with alcohol, or a mixture of alcohol and ether, and then to wash out the sugar from the residue: if we reflect, however, that the dried casein of cow's milk is always slightly soluble, and that of woman's milk is freely soluble in water, the source of error in this system becomes at once obvious. By the adoption of this incorrect method, Payen fixed the amount of casein at $0\cdot23\frac{1}{2}$, while the mean of seventeen analyses performed by myself yielded $3\cdot4\%$, or more than fourteen times as much.

The following is the method that I adopt:¹ a known quantity of milk is evaporated to dryness, and the residue weighed; by this means we determine the amount of water. A weighed portion of the dried and finely-powdered residue is thrice extracted with five or six times its volume of boiling sulphuric ether, in order to remove the fat. After the removal of the fat, the residue is placed in a porcelain basin, is again pulverized, and digested with a little warm water. The pulp which is thus formed is treated with an additional quantity of boiling water, in which it is partially soluble if the analysis is being conducted with cow's milk: it dissolves entirely, with the exception of an inconsiderable quantity of coagulated casein, if woman's milk is used. The solution is then evaporated at a gentle temperature to the consistence of a thin syrup, and is treated with ten or twelve times its volume of alcohol of 0·85, which precipitates the casein. As the casein may retain a little sugar, it is expedient to digest it once or oftener with a little water, and to treat the dilute pulp with spirit; the casein that remains must be thoroughly dried and weighed. The spirituous solution contains the sugar, and the greater part of the extractive matter, from which the sugar cannot be easily separated. A partial separation may be effected in this way: we may dissolve the impure sugar in a little water; on the addition of strong alcohol, the sugar with a very little extractive matter, is precipitated, while the alcoholic solution contains extractive matters and a little sugar. On evaporating this solution to the consistence of a syrup, and adding strong alcohol to it while still hot, some more sugar separates on cooling.

I usually estimate the salts by incinerating a weighed portion of the dried residue of the milk; and, in some cases, I have separated the soluble from the insoluble salts.

This analysis of milk does not yield, as Berzelius² justly observes,

¹ Die Frauenmilch nach ihrem chemischen und physiologischen Verhalten, p. 27.

² Thierchemie, p. 698.

any very accurate results, since casein is slightly soluble in alcohol; although strong cold alcohol takes up only a very small portion, dilute hot alcohol dissolves a considerable quantity. The determination of the sugar and of the extractive matters by the course that I have indicated is still more inaccurate. Berzelius proposes to precipitate the casein (and the butter) by rennet; but it must be observed that, by this means, we do not obtain results of greater accuracy, since a portion of the casein always remains in solution in the whey. This amounts to a considerable quantity in woman's milk, but is comparatively slight in the milk of the cow,¹ and has always to be obtained by means of alcohol from the evaporated solution. In order to precipitate the casein thoroughly by rennet, it would be requisite to supersaturate the free alkali of the milk by acetic or lactic acid; we should then obtain the casein in a state of combination with these acids; in fact, casein precipitated by rennet from non-acidulated milk does in reality exist in this condition.

If we precipitate the casein of cow's milk by sulphuric acid, and decompose the sulphate by carbonate of lime or baryta, we shall obtain soluble compounds of casein with lime or baryta. The casein of woman's milk is very imperfectly precipitated by sulphuric acid.

If albumen is present in the milk, which is sometimes the case, it must be determined by a separate experiment. The milk must be boiled, and the coagulum must be collected and extracted with boiling spirit, in order to remove the sugar and fat; it must then be dried, and its weight estimated. The amount of albumen obtained in this manner is deducted from the amount of casein obtained by the method which has been described, and which must clearly include both the casein and albumen.

[Haidlen² has recently proposed a new method for analyzing milk. It consists in coagulating the milk by gypsum, by which means the error in the determination of the casein that resulted from all former methods, is avoided.

When milk is stirred with about one fourth of its weight of finely-pulverized gypsum, and heated to 212°, it is entirely coagulated; and if the whole is then evaporated to dryness, a brittle mass is obtained, which is easily reducible to powder. From this powder the butter may be extracted by ether; the sugar of milk and soluble salts may be removed by hot alcohol of 0·85; while the caseate and sulphate of lime, and insoluble salts, remain undissolved. The alcoholic solution scarcely exhibits any perceptible opacity on the addition of chloride of barium, showing that no error in the result is occasioned by any of the gypsum being taken up by the alcohol.

About 100 grains of gypsum and four times its weight of milk answer very well. The soluble salts extracted from the milk by

¹ Die Frauennmilch, &c., p. 33.

² Simon's Beiträge, p. 358.

the alcohol may easily be determined by incineration; and since their amount is to that of the insoluble salts in the average proportion of 5 to 7, the amount of the latter may at least be found approximately, and the ascertained weight of the sugar and casein corrected accordingly. But if it be required to determine the salts with perfect accuracy, it is best to incinerate a weighed quantity of milk, and to analyze the residue.

The analyses of Clemm,¹ which will be presently noticed, were made in the following manner: One portion of milk was used for the determination of the water and of the solid residue, and afterwards (by incineration) of the fixed salts. Another portion was evaporated nearly to dryness, and treated with one or two drops of acetic acid to coagulate the casein and render it insoluble. It was then treated with ether, in order to remove the fat, and with water in order to take up the sugar of milk, extractive matters, and salts. The residue was regarded as casein.]

Healthy Milk.

1. Milk before delivery.

The mammary glands secrete a milky fluid during pregnancy, which, at first, differs considerably from normal milk, but, as the period of delivery approaches, gradually approximates to it in its characters. In the first stage of its secretion, albumen predominates, and sugar is almost entirely absent; the albumen gradually gives place to casein, and at the same time, sugar and fat are more abundantly formed. There are no means of obtaining any very accurate information respecting the fluid secreted in the breasts of women previous to childbirth,² but experiments have been made by Lassaigne and myself on this secretion in animals.

I analyzed the milk of an ass pregnant for the first time, and within about fourteen days of her full period of gestation. The fluid was transparent, scarcely opalescent, tenacious, and viscid; it had an alkaline reaction. The microscope revealed a few fat-corpuscles, some granular bodies, composed of accumulated minute fat-vesicles and mucus-corpuscles.

It did not become more gelatinous or stringy on the addition of caustic ammonia; when heated, a considerable quantity of albumen coagulated. The presence of casein was shown, and its amount determined, by the addition of acetic acid, by boiling the fluid till it evaporated to the consistence of an extract, and by then extracting it with boiling spirit. The casein differed from the ordinary casein of cow's milk, in being soluble to a very considerable extent in

¹ The investigations of Clemm are contained in the article "Milch" by Scherer, in Wagner's Handwörterbuch der Physiologie, vol. 2, 1845.

² [Clemm found that the fluid obtained from the breasts of a woman shortly before delivery, contained 5.47% of solid constituents.]

boiling spirit; it partially separated from the clear hot solution on cooling: it seemed rather to resemble the casein of the crystalline lens. After the removal of the fat, by means of ether, it was almost perfectly soluble in water; on the application of heat, the surface of the solution became covered with an irregular film, and the addition of a little dilute acid was followed by a very copious precipitate.

The analysis of this milky fluid yielded, in 1000 parts:

	Analysis 61.
Water	737·00
Solid constituents	263·00
Fat	7·98
Casein	28·93
Albumen	198·34
Extractive matters, traces of sugar and casein, chloride of sodium, and lactate of soda	184·1

The milk of the same ass was examined eight days afterwards; it was less thick and sticky, and rather whiter than before. It more closely resembled true milk in its smell, and it had a mild, faintly sweet taste. It contained, in 1000 parts:

	Analysis 62.
Water	814·0
Solid constituents	186·0
Fat	8·5
Casein	25·0
Albumen	123·9
Extractive matter, with a little sugar, salts	28·6

The change in the constitution of the fluid was very striking; the solid constituents collectively, and especially the albumen, were diminished, while the fat, casein, and sugar, had relatively increased. In the first analysis, the casein formed only one ninth of the solid residue; in the second, it amounted to one seventh.

Lassaigne has observed similar proportions in the fluid secreted by the mammary glands of cows previous to calving. Forty-one days before calving, it contained albumen in place of casein, had an alkaline reaction, a specific gravity of 1063, and, when allowed to stand, deposited a large quantity of cream, from which a very soft sort of butter was obtained. The fluid retained these properties till ten days before calving; it then acquired a milder taste, but still contained albumen in place of casein. If Lassaigne had been acquainted with my method of separating casein from albumen by means of boiling spirit, he would, doubtless, have found casein, as I did, in the asses' milk. It was not till five days after calving, that the fluid resembled ordinary milk; it then had a specific gravity of 1035, and contained casein instead of albumen.

2. Milk immediately after delivery.

The lacteal secretion immediately after delivery differs from the ordinary milk produced after the milk-fever, and has received the

name of colostrum. In woman I found the colostrum thicker than true milk.¹ It had a dirty light yellow colour, an alkaline reaction, no peculiar odour, but a remarkably sweet taste.

[Clemm states that the alkaline reaction very soon disappears. He has found the colostrum become acid in the course of three hours.]

According to other observers, it resembles a thin solution of soap and water (Joannide,²) with drops of oil on its surface. On examining the colostrum with the microscope, a very large number of fat-globules are seen, some of which are larger than those that occur in ordinary milk, and these are frequently observed clinging to one another; besides these, there are granulated, yellow, roundish corpuscles, larger than the milk-corpuscles, which appear to be composed of very minute fat-vesicles; they seem to be peculiar to the colostrum, and were first observed by Donné,³ who states that they occur in woman's milk till the twentieth day, when the milk loses all the characters of colostrum; I have never succeeded in detecting them after the eighth or tenth day.

[According to the observations of d'Outrepont,⁴ the granulated corpuscles usually disappear on the third day.]

The following analysis represents the composition of 1000 parts of the colostrum of a woman. The other analysis represents the average composition of healthy milk, deduced from many observations, and is given in order that the reader may contrast the composition of the colostrum with that of the normal secretion.

	Analysis 63. Colostrum.	Healthy milk of the same individual.
Water	828-0	887-6
Solid constituents	172-0	112-4
Fat	50-0	25-3
Casein	40-0	34-3
Sugar of milk	70-0	48-2
Ash	3-1	2-3

Of the fixed salts, 1-2 were soluble, and 1-8 insoluble in water.

The chemical differences between the colostrum and the milk are at once obvious; the former is much the richer of the two in solid constituents, especially in butter and sugar of milk. The absolute quantity of casein is also greater, but the ratio of the casein to the solid constituents is less than in ordinary milk. The salts are also increased; the aperient property of the colostrum is probably due to the increased quantity of salts and sugar of milk.

¹ Die Frauenmilch, &c., p. 51.

² Physiolog. Mammal. Mulieb. Specim. Halle, 1801.

³ Du Lait, et en particulier de celui de nourrices, etc. Paris, 1837, p. 19.

⁴ [Neue Zeitschrift für Geburtshunde, vol. 10, pp. 1—7.]

3. *Of ordinary milk.*

The ordinary milk of the human female is a white or bluish fluid, and of a sweeter taste than cow's milk. It usually exhibits nothing but the milk-globules under the microscope. It has always an alkaline reaction, which it retains for five or six days before it becomes acid. Its specific gravity varies from 1030 to 1034; the average of a large number of analyses yielded the number 1032. On evaporation, it becomes covered, like every other sort of milk, with a film of coagulated casein; and when the evaporation has been sufficiently prolonged, it yields a brownish extract-like residue which, when dried, is perfectly soluble in water, (with the exception of a little albumen,) and forms a milky fluid. Every thing that precipitates casein, coagulates milk; the mucous membrane of the stomach of an infant a few days old, that has recently died, seems, from my observations, to coagulate woman's milk more perfectly than the mucous membrane of the stomach of the calf.¹ The solid constituents fluctuate between 8·60 and 13·86%. I shall now give some analyses of milk: 1st, the average of fourteen analyses made at different periods with the milk of the same woman; 2d, the analysis of the milk of a woman aged 36 years; 3d, the analysis of the milk of a nurse aged 20 years; 4th, the maxima, and, 5th, the minima, of numerous analyses.

			1.	2.	3.	4.	5.
Water	-	-	883·6	894·0	898·0	914·0	861·4
Solid constituents	-	-	1164	106·0	102·9	138·6	86·0
Butter	-	-	25·3	38·0	28·8	54·0	8·0
Casein	-	-	34·3	34·0	32·0	45·2	19·6
Sugar of milk and extractive matters	-	-	48·2	40·5	36·0	62·4	39·2
Fixed salts	-	-	2·3	1·8		2·7	1·6

The *maximum* table gives the highest amount of each individual constituent, and the *minimum* the lowest that occurred in the whole series of analyses.

[Clemm has recently published the following analyses:

		The 4th day after delivery.	The 9th ditto.	The 12th ditto.
Water	-	879·848	885·818	905·809
Solid constituents	-	120·152	114·182	94·191
Butter	-	42·968	35·316	33·454
Casein	-	35·333	36·912	29·111
Sugar of milk and extractive matters	-	41·135	42·979	31·537
Salts	-	2·095	1·691	1·939

Two analyses of healthy human milk have been made by L'He retier.² He found :

		1.	2.
Water	-	867·8	870·6
Solid constituents	-	132·2	129·4
Butter	-	42·5	52·0
Casein	-	11·7	9·5
Sugar of Milk	-	74·0	63·4
Salts	-	4·0	4·5

¹ Die Frauenmilch, &c., p. 29.

² Traité de Chimie Pathologique, p. 627.

Haidlen,¹ by the method already noticed, found that 1000 parts of woman's milk contained:

		1.	2.
Butter	- - -	13	34
Casein and insoluble salts	- - -	27	31
Sugar of milk and soluble salts	- - -	32	43

In the second analysis, the milk was extremely rich in solid constituents.

Meggenhofen² has also analyzed woman's milk; but, from the method which he pursued, we can place no reliance on the determination of the individual constituents. The dried residue was extracted with alcohol of 0·83, and afterwards with water, as long as any additional matter was taken up. It is evident that fat, some of the sugar, and perhaps even traces of casein must be contained in the alcohol-extract; the water-extract contains the rest of the sugar, some extractive matter, and a great part of the casein. According to Meggenhofen, the solid constituents in woman's milk vary from 10 to 12·56%, and the salts from 1·2 to 2·4%. These numbers correspond very closely with my results.

The analyses gave in 1000 parts:

Water	- - -	827·5	883·5	789·3
Solid constituents	- - -	172·5	116·5	210·7
Fat with sugar and alcohol-extract	- - -	91·3	88·1	171·2
Sugar and casein	- - -	11·4	12·9	8·8
Coagulated casein	- - -	24·1	14·7	28·8

Payen³ has likewise analyzed woman's milk, but his results, especially regarding the amount of casein, differ so very much from those of other chemists, that they can only be explained on the assumption that there was an error in the plan of his analysis. The following numbers represent the mean of three analyses: water, 857·7; solid constituents, 142·3; butter, 51·5; casein, 2·2; residue of evaporated whey, 78·0.

The salts of woman's milk appear, according to my own observations, and those of Meggenhofen, to range at about from one-third to one-fourth per cent. of the fluid; of these, usually about two-thirds are insoluble, and one-third soluble in water: the former consist of phosphate and carbonate of lime, with a little magnesia, and a very small quantity of (phosphate of?) peroxide of iron; the latter, of chlorides of sodium and potassium, with a little chloride of calcium, carbonate of soda, (corresponding with the lactate in the milk,) and a little sulphate of potash, the acid of which does not pre-exist in the milk, but is produced during incineration. Pfaff and Schwartz⁴ found a larger proportion of salts in woman's milk, namely, 0·4407%; they were composed of phosphate of lime,

¹ Annalen der Chemie und Pharmacie, vol. 45, No. 3.

² Dissert. inaug. sistens indigationem lact. mul. chemic. auct. Meggenhofen. Frankf. a. M. 1826.

³ Journal de Chim. méd. vol. iv. p. 118.

⁴ Dissert. inaug. sistens nova experimenta circa lact. princip. constit. Kiel, 1833.

0·25; phosphate of magnesia, 0·05; phosphate of iron, 0·0007; phosphate of soda, 0·04; chloride of potassium, 0·07; and soda originating from lactate of soda, 0·03. Carbonate of lime, sulphate of potash, and chloride of sodium are not noticed, although all other observers concur in finding them in the milk.

Chevallier and O. Henri have instituted some researches on the milk; they precipitated casein by acetic acid, evaporated the fluid portion, and determined the salts by the incineration of the residue. They estimated the part that was consumed, as sugar of milk, and removed the fat from the precipitated casein by means of ether. By this process they obtained much too small a quantity of casein from woman's milk, (since this constituent is only imperfectly precipitated by acetic acid,) and too large a quantity of sugar, which was thus made to include all the destructible constituents, with the exception of the casein and fat. In the other sorts of milk, the precipitation of the casein by acetic acid is also imperfect. The following is the result of their analysis of woman's milk.

Water	-	-	879·8
Solid constituents	-	-	120·2
Butter	-	-	35·5
Dried casein	-	-	15·2
Sugar of milk	-	-	65·0
Salts	-	-	4·5

On the effect of temperament on the milk.

[It has been long believed that the milk of fair women is inferior in its properties to the milk of brunettes. As far as I am aware, the only analyses bearing on this point are those of L'Heretier. He selected two females of equal age, and made them submit to the same diet and mode of life. The following are the results of his analyses:

	A Blonde, aged 22.		A Brunette, aged 22.	
	1.	2.	1.	2.
Water	892·0	881·5	853·3	853·0
Solid constituents	108·0	118·5	146·7	147·0
Butter	35·5	40·5	54·8	56·3
Casein	10·0	9·5	16·2	17·0
Sugar of milk	58·5	64·0	71·2	70·0
Salts	4·0	4·5	4·6	4·5

He appears to have selected the analyses that presented the most marked contrast; for he observes, that if he had taken the mean of all his analyses, the difference between the amount of the solid constituents in the two cases would have been less marked, the average ratio being 120 : 134.

L'Heretier has likewise investigated the changes produced in the milk by a prolonged sojourn in the breast. The two following analyses illustrate the effect thus produced. The milk in each analysis was afforded by the same woman: in the first case it had remained in the breasts for forty hours; in the second, it was obtained after the infant had been sucking for some little time.

		1.	2.
Water	-	901.1	859.0
Solid residue	-	98.9	142.0
Butter	-	34.0	36.5
Casein	-	1.9	13.0
Sugar of milk	-	58.5	78.0
Salts	-	4.5	4.5]

On the changes in the milk dependent on nutrition.

That the character of the food exerts an influence on the quality and quantity of milk, is a fact that has been long known, although the nature of the changes could not be correctly determined. I analyzed the milk of a very poor woman fifteen times at regular intervals during the course of half a year, commencing with the second day after delivery. It so happened that she was suddenly deprived of the means of obtaining even the most ordinary necessities of life. The milk secreted at this period, (the 11th of November,) was sufficiently abundant in quantity, but was very poor in solid constituents, containing only 8.6%. Some days afterwards (the 18th of November) she was placed upon a full and nutritious meat diet. The milk, in consequence, was secreted so copiously as to run spontaneously from the breasts: it left 11.9% of solid constituents. Her circumstances again became very bad, and she was frequently in a state of the utmost destitution: on the 1st of December, while in this condition, the milk again became very thin, and left only 9.8% of solid constituents. I concluded my researches on the milk of this woman, by an examination on the 4th of January, after she had been supplied for two days with a nutritious meat diet: the milk was then very rich in solid constituents, and left a residue of 12.6%.

The following are the results of my examinations on these four occasions; below them is the average of the fourteen analyses to which I have already referred:

		Water.	Solid constituents.	Butter.	Casein.	Sugar and extractive matter.
1. Milk on Nov. 11th	.	914.0	86.0	8.0	35.5	39.5
2. Ditto Nov. 18th	.	880.6	119.4	34.0	37.5	45.4
3. Ditto Dec. 1st	.	920.0	98.0	8.0	39.0	49.0
4. Ditto Jan. 4th	.	873.6	126.4	37.0	40.0	46.0
5. Average of 14 analyses		883.6	116.4	25.3	38.3	48.2

It is evident from these analyses, that however much the nutriment of the mother may vary, no great influence is thereby exerted on the relative quantities of casein and sugar. The changes consist in a greater or less degree of saturation, in the rich yellowish white or the bluish colour, in the quantity of the milk, and in its amount of solid constituents; with the exception of the variation in quantity, all the other changes are dependent on an increase or diminution of the butter; the former occurs under the use of a copious and nutritious diet, the latter when the food is poor and scanty. Donné's¹ proposal for determining the goodness of the milk by a microscopic examination, is founded on incorrect principles: he assumes that the increase

¹ *Du Lait, etc.* p. 54.

of the butter and of the other constituents is simultaneous; an assumption that the above analyses show to be inconsistent with facts.

Changes in the milk, corresponding with the age of the infant.

It seems probable that certain changes will be observed in the milk when the progress of development of the child indicates the necessity for other food. The question is one of considerable physiological interest, and in order to elucidate it I made analyses of the milk of a woman during a period of nearly six months, commencing with the second day after delivery, and repeating my observation at intervals of eight or ten days.

The results would doubtless be more decisive if the experimentalist were able to exclude all disturbing influences: but in almost all cases the exercise of a strict control over the method of living and the nature of the food of the mother, is just as impossible as the exclusion of exciting moral forces.

The fourteen analyses (the colostrum being excluded) gave the following results:

Analyses.		Specific gravity.	Water.	Solid constituents.	Casein.	Sugar.	Butter.	Fixed salts.
66	31st Aug.	1031.6	873.2	126.8	21.2	62.4	34.6	0.84
67	7th Sept.	1030.0	883.8	116.2	19.6	57.6	31.4	1.66
68	8th Sept.	1030.0	899.0	101.0	25.7	52.3	18.0	2.00
69	14th Sept.	1030.0	883.6	116.4	22.0	52.0	26.4	1.78
70	27th Oct.	1034.0	898.2	101.8	43.0	45.0	14.0	2.74
71	3d Nov.	1032.0	886.0	114.0	45.2	39.2	27.4	2.87
72	11th Nov.	1034.5	914.0	86.0	35.3	39.5	8.0	2.40
73	18th Nov.	1033.0	880.6	119.4	37.0	45.4	34.0	2.50
74	25th Nov.	1033.4	890.4	109.6	38.5	47.5	19.0	2.70
75	1st Dec.	1032.0	902.0	98.0	39.0	49.0	8.0	2.08
76	8th Dec.	1033.0	890.0	110.0	41.0	43.0	22.0	2.76
77	16th Dec.	1034.4	891.0	109.0	42.0	44.0	20.0	2.68
78	31st Dec.	1034.0	861.4	138.6	31.9	52.0	54.0	2.35
79	4th Jan.	1032.0	873.6	126.4	40.0	46.0	37.0	2.70

A glance at the three columns of casein, sugar, and butter, will show, that, with few exceptions, 1st, the quantity of casein is at its minimum at the commencement; it then rises considerably, and ultimately attains a nearly fixed proportion; that, 2d, the quantity of sugar is at its maximum at the commencement, and subsequently diminishes; and that, 3d, the butter is a very variable constituent of the milk.

The variations observed in the columns of the sugar and of the casein arise in all probability from those disturbances of the mode of living, and of the tranquillity of the mind, which produce a decided influence on the composition of the milk, and over which the experimentalist can exert no control.

Milk changed by disease.

There are certain morbid states of the system which produce such an influence on the milk that the infant cannot partake of it without

detriment to its health. It is a well-known fact that the milk of women who are exposed to violent mental agitation, to passion, grief, &c. will occasionally produce very serious effects (and sometimes even instantaneous death,) on the infant: and some physiologists and physicians are of opinion that chronic diseases may be transmitted by the milk from the mother to the child.

When we read the statements of trustworthy authors regarding the instantaneously fatal effect produced by the milk on the infant, on the occurrence of a sudden shock affecting the mind of the mother, we cannot deny that some chemical change is produced through the nervous influence on the milk, although we cannot determine the nature of that change. In many cases the milk, possibly, acts only as a conducting fluid, and thus conveys the nervous shock from the mother to the child.

Certain morbid changes in the milk which are dependent on the formation of mammary abscess, may be easily recognised by the microscope, which will then reveal the presence of pus- or mucus-corpuscles. Thus in cow's milk which was drawn from a teat affected with vaccinia, I found a considerable quantity of mucus- or pus-corpuscles, while in the milk drawn from another teat of the same udder there were none.

When a mammary-abscess opens internally, the milk always contains pus-corpuscles, and frequently also blood-corpuscles, if blood has escaped with the pus. Donné¹ has frequently made microscopic examinations of the milk of women with swelled breasts; it resembles, in some measure, the colostrum. In the milk of a cow affected with vaccinia, I found a number of corpuscles, which were very like the yellow granulated colostrum-corpuscles.

I have had an opportunity of examining the milk of a recently-delivered woman, who was in a state of considerable fever in consequence of a violent fit of passion: her child, after partaking of her milk, was seized with vomiting, diarrhoea, and convulsions. The breasts were swollen, tense, and painful: the milk had an alkaline reaction, and apparently possessed the qualities of the ordinary secretion; it had, however, a different and not very easily described animal odour. When boiled it exhibited no albumen, but after evaporation to a certain point it coagulated, and had a marked acid reaction. Another portion that was set aside, coagulated after some hours, and had an acid reaction, a circumstance I have never observed in healthy human milk, which will remain undecomposed for five or six days.

After twenty hours it developed so large an amount of sulphuretted hydrogen, that a slip of paper which had been moistened in a solution of lead, and was then placed in the flask, in a short time became brown. The casein, sugar, and butter, did not seem to have undergone any change, either qualitative or quantitative. In fact there appeared to be little difference between it and the milk that was secreted twenty-four hours before, and six days later, as may

¹ *Du Lait, etc.* p. 40.

be seen by a comparison of analyses 67, 68, and 69: analysis 68 merely exhibits a smaller proportion of solid constituents, which is principally due to the decrease of butter. The differences observable in this milk were undoubtedly connected with the bad effects which it produced on the infant.

The case was altogether different with the milk of a woman who contracted syphilis after the birth of her first child, and who, in consequence of defective or improper medical treatment carried the remains of the disease about her for years. The children which she bore while in this condition, and which were begotten by her husband who also had some suspicious sores on the feet, did well for the first half year, they then became highly scrofulous, and died in a state of marasmus: the first child was perfectly healthy. The milk, when she was suckling her sixth child, which was a year and a half old, and in a dreadfully scrofulous state, exhibited no deviation from the healthy secretion: it appeared rich, tasted and smelled like healthy milk, and had an alkaline reaction, which it retained for the space of six days. Its constituents, casein, sugar, and butter, appeared normal, and there was no peculiarity in their quantitative admixture. (See analysis 64, p. 333.) Hence, although the woman was suffering from a malignant chronic disease, no morbid change was observable in the milk.

Donné¹ has frequently submitted the milk of syphilitic women to microscopic examination, but never observed any deviations from the normal appearance.

Meggenhofen² found that the milk of a syphilitic woman reddened tincture of litmus, and that it was coagulated by protonitrate of mercury, basic acetate of lead, and infusion of galls, but not by hydrochloric or acetic acid, protochloride of tin, neutral acetate of lead, or alcohol of 0.83.

Herberger³ has analyzed a specimen of diseased human milk; he found it composed of water, 89.5; solid constituents, 10.5; casein, 18.3; sugar, 26.9; butter, 23.3; chlorides of potassium and sodium, lactate and phosphate of potash, and an inorganic substance, insoluble in oil of turpentine, 41.6; organic matter soluble in oil of turpentine, 1.6. The latter substance was a yellow extract soluble in water and alcohol. The solution reduced the salts of gold, silver, and platinum, yielded no ammonia by dry distillation, and was not precipitated by tannic acid.

Deyeux⁴ examined the milk of a woman who was liable to frequent nervous attacks: he found that simultaneously with these seizures, the milk became transparent and viscid, like albumen, and did not reassume its normal condition for some time.

¹ Op. cit. p. 52.

² Dissert. inaug. etc. p. 16.

³ Journal für prakt. Chemie, vol. vi. p. 284.

⁴ Crelle's Chemische Annalen. vol. i. p. 369.

Other changes in the milk.

Certain substances which are not included in the ordinary constituents of the milk are sometimes detected in it, after having been taken into the system, either as food or medicine. It is not to be expected that all the substances which enter the circulating fluid and are separated by the kidneys, should be found in the milk, since the absorbents appear to exert a sort of selective power, and would thus reject those substances which occur in the blood, but which would produce an injurious effect on the tender frame of the infant, if they entered into the milk.

I have sought in vain for ferrocyanide of potassium in the milk of women who were suckling, and to whom I have given it in doses of six drachms. This salt is known to enter very readily into the circulation, and is found after a very short interval in the urine. After the lapse of two days I gave the same woman twenty-three grains of iodide of potassium, but I could detect no trace of this salt in the milk. Lastly, I attempted in vain to detect sulphate of magnesia in the milk of a woman who was suckling, and to whom I had administered it in a sufficient dose to act as a laxative.

For the particulars of these experiments I must refer to my essay 'On the Milk of Woman, in its Chemical and Physiological relations.' From these observations I think that I am justified in the conclusion that energetic substances, which are foreign to normal milk, either do not enter into that secretion at all, or if they do, they undergo modifications, which render them more compatible with the organism. Although I could not detect the sulphuric acid of the sulphate of magnesia in the milk, it is very probable that the magnesia entered the milk as a lactate, while the sulphuric acid was carried off by the urine as a sulphate.

Peligot, however, has detected iodide of potassium in asses' milk; and Herberger in the milk of woman. [I have on several occasions observed the ordinary indication of iodine on the addition of xyloidin, or of starch and a drop or two of nitric acid to the urine of infants at the breast during the period of the mother taking three grains of hydriodate of potash thrice a day—a convincing proof that the salt has entered the milk.] Mercurial medicines used by women who are suckling have never been traced in the milk, [although their effects on the infant are undoubted.]

ON THE MILK OF ANIMALS.

Colostrum of animals.

In the colostrum of the cow Chevallier and Henri found: water, 803.8; casein, 170.7; and butter, 26.0. They describe it as a dark yellow, thick, viscid fluid, sometimes marked with fine streaks of blood; it has an alkaline reaction, contains little butter, (as shown by the analysis,) coagulates on heating, and in all probability contains a

mixture of albumen and casein, in the same manner as I observed in the mammary secretion of the ass a short time before delivery.

Boussingault and Le Bel¹ found in the colostrum of a cow, the day after calving: water, 784·0; casein with albumen, 151·0; butter, 26·0; sugar, 36·0; and earthy salts, 3·0. (I shall presently describe a specimen of cow's milk resembling colostrum, which was analyzed by me.)

In the colostrum of the ass Chevallier and Henri found: water, 828·4; casein, 123·0; butter, 5·6; and sugar, 43·0;—and in the colostrum of the goat: water, 641·0; casein, 275·0; butter, 52·0; and sugar, 32·0.

The 170·7 parts of casein found by Chevallier and Henri in the colostrum of the cow, consisted of 150·7 of a substance coagulable at a boiling heat, which they termed colostrum-casein, and of 20 of a substance remaining in the whey, to which they applied the name of *matière muqueuse*.

The 123 parts of casein in the colostrum of the ass consisted of 116 of the former, and 7 of the latter substance; and in the colostrum of the goat they were in the proportion of 245: 30. These numbers approximate very closely to the proportional amount of casein and albumen in asses' milk, previously to delivery. (See page 331.)

1. Cow's milk.

Cow's milk is a rich white fluid of an agreeable, somewhat sweetish taste, and of a peculiar odour; when allowed to stand, the fatty portion (cream) collects on the surface; when boiled, it becomes covered with a film of coagulated casein. My own observations and those of others show that, when fresh, it has always an alkaline reaction. D'Arcet and Petit have, however, found it to be acid. This discrepancy may probably be explained by the circumstance of the speedy conversion of the sugar into lactic acid, which is sometimes noticed in cow's milk. The state of acidity is hastened by a heightened temperature, and is most rapidly induced by being brought in contact with rennet. The specific gravity of cow's milk varies from 1030 to 1035.

We possess several analyses of cow's milk; it has been examined by Herberger and myself by the method I have previously explained, and our results approximate closely. The third of my analyses (No. 82) represents the milk a short time after calving, while it still retained the character of colostrum. Boussingault and Le Bel have also analyzed normal milk with the view of ascertaining the influence of various sorts of fodder on its composition; by the adoption of the French method, to which I have already alluded, they obtained too little casein and too much sugar. I shall give the mean of twelve of their analyses:

¹ Annal. de Chim. et de Phys. May, 1839.

	F. Simon.			Herberger.		Lecans.	Bonnington and Le Bel.	Cherelle and Henr.
	An. 80.	81.	82.	1.	2.			
Water	857.0	861.0	823.0	853.0	862.0	868	874.0	870.2
Solid constituents	143.0	139.0	177.0	147.0	138.0	132	126.0	129.8
Butter	40.0	38.0	55.0	38.9	37.5	36	39.0	31.3
Casein	72.0	68.0	67.0	69.8	67.0	56	34.0	44.8
Sugar and extractive matter	29.0	29.0	51.0	31.3	26.3	40	53.0	47.7
Fixed salts	6.2	6.1	13.0	7.0	7.2			6.0
Earthy salts							2.2	

[Haidlen found, in the milk of a cow: water, 873; solid residue, 127; butter, 30; casein and insoluble salts, 51; sugar and soluble salts, 46. He has carefully studied the salts of the milk, and is of opinion that the carbonate of soda that occurs in the ash does not originate from a lactate in the fresh milk, but exists there combined with casein. The salts are combinations of phosphoric acid with lime, magnesia, and peroxide of iron; chlorides of sodium and potassium, and soda in combination with casein.

The following numbers represent the amount of the various salts found in 1000 parts of milk: the per centage of each constituent is added in order to show the slight variation to which the different salts are liable, in relation to the mass of the ash.

		1. Per centage.	2. Per centage.
Phosphate of lime	-	2.31	47.1
Phosphate of magnesia	-	0.42	8.6
Phosphate of peroxide of iron	-	0.07	1.4
Chloride of potassium	-	1.44	29.4
Chloride of sodium	-	0.24	4.9
Soda	-	0.42	8.6
		4.90	100.0
		6.77	100.0]

Berzelius¹ found, in skinned milk: water, 928.75; casein, with butter, 26.00; sugar, 35.00; alcohol-extract, with lactic acid and salts, 6.00; chloride of potassium, 1.70; alkaline phosphates, 0.25; phosphates of lime and magnesia, with traces of iron, 2.30. The cream consisted of: water, 920; butter, 45; casein, 35.

Pfaff and Schwartz² estimate the fixed salts at 0.3742, scarcely more than half the quantity obtained by Herberger and myself. They contained phosphate of lime, 0.1805; phosphate of magnesia, 0.0170; phosphate of iron, 0.0032; phosphate of soda, 0.0225; chloride of potassium, 0.1350; and lactate of soda, 0.0115.

A comparison of my analyses of cow's milk with those of woman's milk will show that the former contains the larger amount of solid constituents, especially of casein, while the latter contains the greater quantity of sugar.

¹ Thierchemie, p. 701.

² Diss. inaug. sist. nova experim. circ. lact. princip. constit. Kiel, 1833.

2. *Asses' milk.*

Asses' milk is a tolerably rich white fluid, with a sweeter taste than cow's milk, and occasionally having an acid reaction. Its specific gravity fluctuates between 1035 and 1023. I found the milk of an ass, about a year after foaling, to be composed of:

	Analysis 83.
Water	907.00
Butter with some lactic acid	12.10
Casein	16.74
Sugar, with extractive matter and alkaline salts	62.31

The following is the mean of several analyses of asses' milk made by Peligot,¹ his numbers approximate pretty closely to mine:

Water	904.7
Butter	12.9
Casein	19.5
Sugar, extractive matter, and salts	62.9

Chevallier and Henri found in 1000 parts of asses' milk:

Water	916.3
Solid constituents	83.5
Butter	1.1
Casein	18.2
Sugar	60.8
Salts	3.4

Asses' milk contains a smaller amount of solid constituents, especially of casein and butter, than cow's milk; it also differs from it in its great abundance of sugar and extractive matter, in which peculiarity it resembles woman's milk.

3. *Mare's milk.*

Mare's milk is very rich in solid constituents; it has a specific gravity of 1034.6—1045.0; it contains little butter, but a large amount of sugar. Stipriaan, Luiiscius and Bondt obtained from it 0.8% of cream, 1.62% of casein, and 8.75% of sugar. I obtained a yellow, viscid, saltish, and nearly inodorous fluid from the teats of a mare expected to foal shortly: it coagulated on heating, exhibited a few fat-vesicles and granular corpuscles under the microscope, and acetic acid separated a small quantity of casein. It contained 5% of solid constituents, of which only 0.15% was butter. The solid constituents consisted for the most part of albumen, mixed with a little casein, butter, and extractive matter.

4. *Goat's milk.*

Goat's milk is a very rich white fluid, of specific gravity 1036, with a peculiar disagreeable odour arising from the hircic acid which is present in the butter. Its solid constituents are as abundant as those of cow's milk, and it contains in 1000 parts:

¹ Annal. de Chimie et de Physique, Août, 1836, p. 432.

	Chevallier and Henri.	Clemm.	Boysen.	John.	Payen.	Stip., Luis., and Bondt.
Water	868.0	865.175	892.8	849.3	855.0	744.4
Butter	33.2	42.507	29.9	11.7	40.8	45.6
Casein	40.2	60.321	52.9	105.4	45.2	91.2
Sugar	52.8	44.065	20.7	23.4		43.8
Salts	5.8					
Residue of whey					58.6	
Cream						75.0

[An analysis of the mammary secretion of a he-goat has been recently made by Schlossberger.¹ The animal was four years old, and had given undoubted proof of his generative powers. The fluid obtained by repeatedly milking the animal, had the colour, consistence, and taste of milk, and was perfectly devoid of any unpleasant odour. Under the microscope, the globules appeared numerous, and a considerable amount of cream separated after standing for some time. The milk was analyzed according to Haidlen's method, and found to contain:

Water	-	-	-	-	850.9
Butter	-	-	-	-	26.5
Casein (with salts insoluble in alcohol)	-	-	-	-	96.6
Sugar (with salts soluble in alcohol)	-	-	-	-	26.0

The milk left .782% of ash, of which .325 were soluble, and .457 insoluble in water. This case is interesting in reference to the theory of secretion; it seems to show that the secretion of milk is independent of any peculiar condition of the blood incident to pregnancy, but that it depends far more upon the development of the secreting organ.]

5. Ewe's milk.

Ewe's milk is an extremely rich, thick, white fluid, with an agreeable smell and taste, and having a specific gravity of 1035 to 1041. Stipriaan, Luisius, and Bondt found in 1000 parts:

Water	-	-	-	-	632.0
Solid constituents	-	-	-	-	368.0
Butter	-	-	-	-	58.0
Casein	-	-	-	-	153.0
Sugar	-	-	-	-	42.0
Cream	-	-	-	-	115.0

We cannot help thinking that in this, as well as in the previous analysis by the same chemists, the amount of solid constituents, and especially of the casein, is higher than is likely to be correct. Chevallier and Henri found in 1000 parts:

Water	-	-	-	-	856.2
Butter	-	-	-	-	42.0
Casein	-	-	-	-	45.0
Sugar	-	-	-	-	50.0
Salts	-	-	-	-	6.8

¹ Annalen der Chemie und Pharmacie, 1844.

6. Bitches' milk.

I have made two analyses of the milk of a bitch of the bull-dog breed. The milk was drawn from one of the teats that was not used by the pup: it was very thick, (whereas the milk from the teats which the pup was in the habit of sucking was very thin,) had a disagreeable animal odour, and a rather saltish, mawkish, but not sweet taste. A period of ten days elapsed between the two analyses.

		Anal. 84.	Anal. 85.
Water	-	657.4	689.0
Solid constituents	-	342.6	318.0
Butter	-	162.0	133.0
Casein	-	174.0	146.0
Extractive matter and traces of sugar	-	29.0	30.0
Fixed salts	-	15.0	14.8

This milk is distinguished from every other kind of milk that I have examined, by the immense amount of its solid constituents, and by the nearly total absence of sugar.

[Clemm examined the milk of a bitch. Its specific gravity was 1033; and 1000 parts yielded 274.689 of solid constituents, consisting, for the most part, of casein and butter, but still giving undoubted indications of the presence of a very small quantity of sugar. The bitch was fed entirely on flesh.]

On diseased milk in animals.

The changes produced by disease have been especially studied in cow's milk. The milk may contain mucus, pus, and blood, under similar conditions to those which we have noticed in woman's milk. (See page 338.) These substances are easily detected by the microscope.

Through the kindness of Dr. Bremer, I obtained some milk from the udder of a cow affected with vaccinia, and indeed one portion of the milk was taken from a teat covered with the eruption, while the rest was drawn from a healthy teat. The two specimens differed both chemically and physically: the milk from the diseased teat was strongly alkaline, had a slightly saline taste, and exhibited under the microscope a number of mucus- or pus-corpuscles. It became gelatinous on the addition of a spirituous solution of caustic ammonia; it yielded a precipitate of mucus- or pus-corpuscles on standing, while the upper portion became clear; and it coagulated on heating, in consequence of the presence of albumen.

The milk from the healthy teat had a mild acid reaction, tasted like ordinary milk, contained no pus- or mucus-corpuscles, but a larger proportion of fat vesicles than the diseased milk. These analyses gave:

			Analysis 86. Milk from the healthy teat.	Analysis 87. Milk from the diseased teat.
Water	-	-	912·10	935·40
Solid constituents	-	-	87·90	64·60
Butter	-	-	19·58	12·05
Casein	-	-	40·62	
Casein, with pus or mucus, and albumen	-			31·40
Sugar, with alcohol-extract, lactates and chloride of sodium	-		29·36	
Extractive matter, with chloride of sodium, lactate of soda, and a little sugar	-			16·18
Water-extract	-	-		0·32
Salts soluble in water	-	-	3·87	6·42
Salts insoluble in water	-	-	3·20	2·42

The great increase of the soluble salts, especially of the free alkali, the presence of albumen, and the almost total absence of sugar, are the points most worthy of notice in the morbid specimen.

Herberger¹ has analyzed the milk of cows suffering from the grease, and found it materially affected. In the first stage of the disease he found that the milk only coagulated imperfectly on the addition of rennet, in consequence of the increased quantity of alkaline salts; moreover (and probably for the same reason) the fat-vesicles were not distinct, as they usually are, but merged into each other. In the second stage, only a few fat-vesicles were observable, the coagulation by rennet was very imperfect, and the milk, which was thick and viscid, had an unpleasant putrid smell and taste. In both stages the sugar and casein were below their normal proportions, but the amount of salts was increased; the presence of carbonate of ammonia (an ingredient never before observed in the milk) was detected. His analyses gave the following results:

	In the first stage.		In the second stage.		Healthy milk.
	1.	2.	1.	2.	
Water	869·0	872·4	874·1	879·3	857·5
Solid constituents	131·0	127·6	125·4	120·7	142·5
Fat	39·0	38·5	38·2	37·9	38·2
Casein	52·4	51·0	50·0	49·0	68·4
Sugar	22·8	21·0	21·0	19·0	28·8
Fixed salts	16·8	17·1	16·6	13·9	7·1
Specific gravity	1033·6	1033·0	1033·1	1029·1	1033·7

The most striking changes in the diseased milk are the diminution of the solid constituents, especially of the casein and sugar, and the extraordinary increase of the salts. Hence the modifications of the fluid in this instance closely resemble those in my analyses in the preceding page.

Donné found that the milk of the cow during "la maladie aphtheuse," resembled colostrum. It was less fluid and homogeneous in its mixture than ordinary milk; it became viscid on the addition of ammonia, and, besides the ordinary milk-corpuscles, the microscope revealed mucus-granules and tubercular (mulberry-form) corpuscles.

¹ Pharm. Centralblat. Jahrg. 1840, p. 138.

Of other changes in the milk.

The passage of various substances into the milk has been more frequently observed in animals than in the human species. Peligot detected iodide of potassium, and chloride of sodium in the milk of the ass, after internal administration. The salts of iron, zinc, and bismuth, are also said to enter it in minute quantities.

The sulphates of soda and potash, sulphuret of potassium, and the mercurial salts have never been met with in the milk. The smell, taste, and colour of vegetable substances are taken up by it.

The milk is sometimes observed to become blue on its surface after standing for 24 to 48 hours, and the tint gradually diffuses itself through the whole fluid: the milk has also been observed to turn yellow in a similar manner. Fuchs¹ has carefully investigated this phenomenon, and has detected in milk of this nature a peculiar infusorium, to which he has applied the name *vibrio cyanogenus*; it is not of a blue colour itself, but it appears to have the power of gradually changing the milk to this tint. When removed from the milk, and placed in an infusion of marsh-mallows, these animalcules increase in size, and communicate a faint blue tinge to the fluid; in this way they may be preserved for a long time. Closely allied to this animalcule is the *vibrio xanthogenus*; they are sometimes found together in milk, and Fuchs had also an opportunity of observing them in milk which had become yellow, a much more rare change than the former.

CHAPTER V.

SECRETION OF THE MUCOUS MEMBRANE.

Mucus.

ALL the internal parts of the animal body which are connected by direct continuity with the external surface, are covered by a soft velvety and highly vascular coat—the mucous membrane, which in its turn is protected by a delicate layer of epithelium.²

The mucous surfaces, especially when they are in a state of irritation, secrete a viscid, stringy, and often tough fluid; occasionally it is

¹ Beiträge zur näheren Kenntniss der gesunden und fehlerhaften Milch der Haustiere. Magazin für die gesammte Thierheilkunde, Jahrg. 7. Stück 2.

² According to Henle the epithelium consists of one or more layers of cells, which, from the peculiarity of their form, are arranged in three groups: 1st, Pavement epithelium [the scaly epithelium of Bowman], fig. 14 a, which occur in the mouth, in the intestinal canal as far as the pylorus, in the vagina, &c.: 2d, Cylinder epithelium, [the prismatic of Bowman, the columnar of Todd,] fig. 14 b, having a conical form, and arranged perpendicularly to the basement membrane; this form occurs in the portion of the intestinal canal below the pylorus, in the gall-bladder, and in the male genito-urinary apparatus: and 3d, The ciliated epithelium, fig. 14 c, which resembles the cylinder epithelium in form, and has its free edges armed with cilia. This occurs in the respiratory organs, in the uterus, and Fallopian tubes.

clear and colourless, but most commonly it is turbid, of a faint yellow or grayish white colour, and is frequently of sufficient consistence to separate in gelatinous globular masses, or tough flocculi.

Of normal mucus.

The transition from healthy to diseased mucus is so indefinitely characterized, that it is almost impossible to draw a strict line of demarcation between them, and the same remark is equally applicable to the further change of the diseased secretion into pus: hence it is not very easy to form a distinct conception of what normal mucus really is.

Henle states that in the same manner as the outer surface of the external skin is continually peeling off and giving place to the layer beneath it, so there is also a continuous desquamation or separation of the epithelium of the mucous surfaces, which sometimes occurs in men who are in other respects healthy, to such an extent that thick clots of mucus are expectorated in the morning; which on being examined with the microscope, contain merely epithelium-cells. This, which is formed by a mere act of separation from the uppermost layer of epithelium, is regarded by Henle as normal mucus; he gives it the name, however, of epithelium, and restricts the term mucus to the morbid secretion of the mucous surfaces in which mucus-corpuscles (of which I shall speak presently) are found. I have always found these corpuscles in the secretion from the nasal and pulmonary mucous membrane of perfectly healthy persons; they are mixed in a small quantity with the epithelium-cells, and become increased when the mucous membrane is irritated.

Physical character of mucus.

Normal mucus, when fresh and recently secreted, is denser than water, and when mixed with that fluid it gradually sinks to the bottom of the vessel, unless it should be hindered from doing so by extraneous causes.

Dried mucus sinks very rapidly: normal mucus from the lungs or nostrils usually floats on water for a considerable period; in fact it was regarded as characteristic of mucus to float on water, in contradistinction to pus, which always sinks. A more careful investigation enables us to trace the floating of the mucus to two causes: first to the number of air-bubbles that are entangled in it, (after the removal of which it sinks;) and, secondly, to the proportionally small amount of solid constituents in the secretion. The insolubility of fluid mucus in water is the cause of the long retention of the air-bubbles. When mucus contains pus, the proportion of solid constituents increases, the fluid portion diminishes, and its place is supplied by albumen. Water rapidly permeates mucus in this state, the air-bubbles escape, and it speedily falls to the bottom in consequence of its specific gravity.

v. Mucus from the bladder or from the intestines does not swim in water in consequence of the absence of air-bubbles.

When some fresh, fluid, transparent, nasal, or bronchial mucus is examined under the microscope, it is found to consist of a liquid in which minute rounded or prolonged corpuscles of a granular appearance (mucus-corpuscles) are enclosed, which do not exhibit any independent motion, in consequence of the thick viscid nature of the fluid in which they are suspended; but when the fluid is stirred they are seen to move with it. In addition to the mucus-corpuscles, some epithelium-cells are also observed and a finely-granulated substance which pervades the whole fluid, and can only be seen with a good light. Nasal mucus, from my own observations, is represented in fig. 15; *a a* mucus-corpuscles, *b b* epithelium cells; *c c* the faintly granular substance.

According to Henle the diameter of the mucus-corpuscles varies from 0·003 to 0·007 of a line: according to Vogel from 0·004 of a line: Gruby¹ considers them from 2 to 4 times the size of the blood corpuscles. They are prolonged, oval, or round, and when observed in fresh mucus have a clear well-defined contour, a pale gray colour, a granular appearance, and sometimes give faint indications of one or more nuclei. After remaining for some time in water, the mucus-corpuscles become more or less swollen, paler, and more transparent; the granular appearance on the external capsule disappears, and one or more nuclei may be observed in the interior of the cell. The external capsule frequently becomes so colourless as to render its detection difficult.

The epithelium-cells appear under the microscope in the form of elliptic discs; according to Gruby, the axis major varies from 0·013 to 0·0333 of a line, and the axis minor from 0·010 to 0·016 of a line: the surface is frequently irregular, wrinkled, or plicated. We sometimes find them swollen and vesicular, and sometimes, but more rarely, almost circular or elliptic. The nucleus is of the same prolonged form as the mucus-corpuscle; it is granular and rather darker coloured. If mucus is frequently observed, the transition of mucus-corpuscles into epithelium-cells may easily be seen. We have attempted to illustrate this progressive change in *d, e, f*, fig 15.

Chemical character of mucus.

The action of chemical reagents on the epithelium-cells and mucus-corpuscles may easily be observed under the microscope. The former are not affected by the addition of water or of dilute acids; they disappear, however, under the influence of caustic alkalies or concentrated acids. According to Gruby, solutions of the ordinary earthy, and metallic salts effect no change on the epithelium-cells. The mucus-corpuscles are very differently acted on. Dilute acetic, oxalic, and tartaric acids speedily deprive the capsules of the mucus-corpuscles of their granular appearance. The corpuscles themselves become round and transparent; the nuclei become apparent, the cap-

¹ *Observationes Microscopicae ad Morphologiam Pathologicam.* Vindobonæ, p. 15.

sules at length disappear, and the nuclei frequently divide into several granular bodies, so that in place of the mucus-corpuscles previously visible, there are at last only two, three, or more rounded granules to be seen.

Dilute mineral acids do not produce these changes in the capsule of the mucus-corpuscule, which remains unchanged, as shown by the observations of Gütterbock, Vogel, Gruby and myself. Dilute, as well as concentrated solutions of the alkalies and their carbonates render the capsules clearer, and ultimately dissolve them. The free fixed alkalies produce these changes more rapidly than their carbonates; free ammonia much less rapidly than free potash.

The liquid portion of the mucus always exhibits a decidedly alkaline reaction: when examined under the microscope it appears like a clear fluid, in which, with a very good light, a faint granular appearance is perceptible. On the addition of a little water, a decided coagulation may be observed, and an extremely fine granular precipitate is formed. Acetic, and indeed any weak acid produces a similar effect, but the precipitate is more copious, and forms a grayish granular film, sufficiently strong to admit of traction. The free alkalies and their carbonates do not precipitate this fluid.

It is clear from the preceding observations that mucus is composed of two distinct parts, the cells and the fluid. The viscosity of the secretion evidently pertains to the latter, and the ingredient that gives rise to this property must be contained in it in a state of solution, as is obvious from microscopic examination. There can, I conceive, be no doubt that the principal constituent of the fluid, *mucin*,¹ is held in solution by means of an alkali, since water (by taking up the alkali) is sufficient to precipitate it, and the effect is produced in a much higher degree by the addition of a free acid.

When mucus is allowed to remain in contact with water, a slight quantity of the mucin always dissolves, probably through the aid of a free alkali; hence it is that the water in which the sputa, during catarrhal affections, are allowed to float, always becomes slightly turbid on the addition of acetic acid.

In addition to the mucin, the fluid portion of the mucus also contains a small quantity of extractive matters and salts, (especially lactate of soda and chloride of sodium,) and either no albumen, or at any rate a mere trace. The contents of the mucus-corpuscles are not accurately known; in all probability they contain a fluid in ad-

¹ [Simon observed the great similarity between mucin and pyin; the researches of Eichholz seem to show that these substances are identical. The substance described by Eichholz as pyin differs from the protein-compounds in being precipitated from an alkaline solution by an aqueous solution of iodine and by distilled water. A considerable excess of water dissolves a slight portion of it. Dilute mineral acids, when carefully added, precipitate it, but when in slight excess, immediately re-dissolve it; moreover, ferrocyanide of potassium causes no precipitate in a clear acid solution, but a turbidity is produced by the same substances that throw it down from its alkaline solutions. Acetic, tartaric, and oxalic acids precipitate, but do not redissolve it, and a solution of alum, gradually added, produces a precipitate insoluble in an excess of the test. On evaporating an alkaline solution of mucin on the water-bath, it becomes covered with a film of coagulated mucin which is difficult of solution in water.]

dition to their nuclei. The fat that occurs in mucus is probably contained in the corpuscles, for no fat-vesicles are generally observed in fresh mucus, but after the solution of the corpuscles by the addition of acetic acid, a few fat-vesicles make their appearance; indeed in some of my observations, the nuclei of the mucus-corpuscles, have seemed to lose their dark granular appearance, and, after a time, to become clear and like minute fat-vesicles. The nuclei of the mucus-corpuscles do not appear to undergo this change invariably; there are probably different stages of development, and on the assumption that the nuclei of the least-developed corpuscles are composed of fat, the relative increase of fat will clearly correspond with the amount of mucus that is secreted.

It follows, from the preceding observations, that mucus contains the following constituents: mucus-corpuscles, epithelium cells, mucin, small quantities of extractive matters and fat, chlorides of sodium and potassium, alkaline lactates, a little carbonate of soda and phosphate of lime, and sometimes a minute quantity of albumen. In order to separate these constituents I adopt the following course.

A known weight of mucus must be washed with distilled water and evaporated to dryness on the water-bath. The residue must be finely triturated and repeatedly extracted with boiling ether in order to remove the fat; it must then be boiled in spirit of 0·91 as long as any additional matter is dissolved. The spirituous solution must be evaporated to a small syrupy residue, and alcohol of 0·85 added, in order to precipitate any dissolved mucin, caseous matter, water-extract and pyin: the alcoholic solution, containing the alcohol-extract and lactates is also to be evaporated. The portion undissolved by boiling spirit of 0·91, consists of mucin with cells, and traces of albumen, if the previous qualitative investigation has shown that this substance is present.

In order to determine the salts, a portion of the dried residue must be submitted to incineration. It is difficult to obtain a white ash in consequence of the fusion of the salts. The chlorides may be extracted with spirit; the residue must be then treated with acetic acid, in order to convert the carbonates, which have arisen from the incineration of the alkaline lactates, into acetates, which may be extracted with alcohol. Any thing that still remains, is composed of phosphates and perhaps sulphates, in very minute quantity, together with traces of iron and silica.

I have analyzed mucus both from the nose and lungs, during pulmonary catarrh, but as I cannot regard these cases as illustrations of normal mucus, I shall defer their consideration for the present. From an analysis of nasal mucus, made by Berzelius, it appears that there are in 1000 parts:

Water	-	-	-	-	933·7
Mucin	-	-	-	-	53·3
Alcohol-extract and alkaline lactates				-	30
Chlorides of sodium and potassium				-	5·6
Water-extract with traces of albumen and phosphates				-	3·5
Soda, combined with mucus				-	3·9

Consequently, Berzelius found no fat, but he detected traces of albumen.

The foregoing remarks refer especially to the mucus of the nostrils and lungs, but as the physico-chemical properties of all sorts of mucus are not quite the same, I shall briefly communicate my own observations and those of Berzelius on the different varieties of mucus.

1. Nasal mucus.

Nasal mucus generally occurs as a gelatinous or fibrous, and nearly transparent mass; after complete evaporation it remains in the basin as a yellow, and tolerably transparent coating. It contains epithelium-cells and a few mucus-corpuscles, is not soluble in water, but if it remains in contact with that fluid for a considerable time it yields some mucin, in consequence of which the addition of acetic acid to the water produces a very slight turbidity. When water containing mucus is submitted to filtration, the latter remains on the filter and gradually solidifies. Berzelius has observed that it may be dried and again diffused through water repeatedly, without changing its properties; it ultimately, however, becomes opaque, yellow, and apparently purulent. When boiled with water it does not shrivel and harden, but only slightly contracts, and may be diffused by shaking. On cooling, it again becomes tenacious and viscid. By dry distillation of evaporated mucus we obtain carbonate of ammonia and Dippel's oil. Mucus dissolves in dilute sulphuric acid; in the concentrated acid it becomes dark-coloured and is decomposed. Dilute nitric acid causes a superficial coagulation; acetic acid induces a degree of contraction, and the mucus does not dissolve in it at a boiling heat. On the addition of caustic alkalies, it, at first, becomes tough and thick, but subsequently dissolves into a thin fluid.

2. Bronchial and pulmonary mucus.

These are very similar to nasal mucus. They separate into clear and gelatinous, or else into gray or yellowish flocculi, which remain suspended in water for some time, but ultimately sink to the bottom.

[Nasse¹ has analyzed pulmonary mucus expectorated in the morning by a healthy man. Analysis No. 1 refers to the mucus itself, and No. 2 to the solid residue.

		1.	2.
Water	- - -	955.520	
Solid constituents	- - -	44.480	
Mucin, with a little albumen	- - -	23.754	53.405
Water-extract	- - -	8.006	18.000
Alcohol extract	- - -	1.810	4.070
Fat	- - -	2.887	2.490
Chloride of sodium	- - -	5.825	13.095
Sulphate of soda	- - -	0.400	0.880

¹ Journal für praktische Chemie, vol. 9, p. 59.

Carbonate of soda	-	-	0·198	0·465
Phosphate of soda	-	-	0·080	0·180
Phosphate of potash, with traces of iron	-	-	0·974	2·190
Carbonate of potash	-	-	0·291	0·655
Silica, and sulphate of potash	-	-	0·255	0·570]

3. *Mucus from the intestinal canal.*

When evacuated with watery motions after the administration of a purgative, I found it occurring in yellow gelatinous masses, which, on being examined with the microscope, were observed to contain a large quantity of mucus-corpuscles. Berzelius found that the mucus discharged with the faeces becomes hard and black on drying; if it is then placed in water it becomes softer, and if the water contains any free alkali it again becomes viscid. It is thoroughly soluble in caustic potash, and it may be precipitated from its alkaline solution by the addition of any acid. According to Gmelin,¹ the mucus from the small intestines of dogs and horses appears, after being washed in cold water, in the form of white shreds or flocculi. Dilute acids increase its coagulation, but concentrated acetic acid dissolves the greater part. It also dissolves in the alkalies, from which it may be precipitated by an acid.

4. *Mucus from the gall-bladder.*

When bile is submitted to filtration a certain quantity of mucus which is suspended in the bile is detained on the filter, while another portion chemically combined with an alkali passes through in a state of solution, and may be precipitated by an acid: the latter has, however, lost the characteristic viscosity of mucus. If the acid be removed by means of an alkaline carbonate, the mass does not become viscid; if, however, instead of a carbonate, a caustic alkali is employed, the viscosity is restored. If the mucus of the gall-bladder is precipitated by alcohol, the viscosity disappears, it is restored, however, by being washed in water. When dried, it becomes transparent and yellow; on the addition of water it swells, and is rendered opaque, but not viscid.

Mucus from the urinary bladder.

Vesical mucus is always present in the urine, but only in very small quantity in the normal secretion. In recently discharged urine it cannot be detected with the naked eye, but after the fluid has stood for some time, there are formed light, often hardly perceptible nebulae of sinking mucus, in which the microscope reveals mucus-corpuscles and epithelium cells. On filtration the mucus remains on the paper in the form of colourless flocculi; it contracts and ultimately forms a glistening varnish-like coating, which does not resume its former appearance on being moistened with water.

¹ Handbuch der theoretischen Chemie, vol. ii. p. 1118.

According to Berzelius it is insoluble in sulphuric acid, but the greater part of it dissolves in acetic and hydrochloric acids: ferrocyanide of potassium throws down a precipitate from these solutions.¹

Morbid Mucus.

It is well known that any irritation will increase the secretion of mucus in an extraordinary degree; this is seen in the secretion of the mucous membrane of the nostrils and lungs during a common cold or catarrh. The mucus is then materially changed; at the commencement of the attack it is generally thinner than usual; but, towards the termination, it becomes thicker; the epithelium cells diminish, while the mucus-corpuscles increase in number; the reaction continues alkaline; in fact, in most cases it is more strongly so than in the normal state; the fat is increased, and always contains cholesterol; and at the same time there is an excess of albumen.

Gruby found that mucus secreted by the nasal mucous membrane during a state of irritation of that surface, was white, of the consistency of the white of eggs, and had a saline taste. When examined with the microscope, there were only a few epithelium cells and mucus corpuscles to be seen.

I have analyzed nasal mucus which accumulated in the upper part of the nose of a man aged thirty years; it generally came away in the form of thick, tough, yellow lumps, about the size of an ordinary bean, or, if it had only been retained in the nostril for a shorter period, it was obtained as an extremely copious, tough, yellow fluid; it was invariably discharged from only one nostril. This mucus was devoid of odour, had an alkaline reaction, and being moistened with water, (in which it sank,) it exhibited an extraordinarily large quantity of epithelium-cells, and a few mucus-corpuscles, connected by a pretty thick membrane of coagulated mucin. When the mucus was gently dried and pressed between the fingers, they presented the same glistening appearance as if they had been pressing fat; no fat could, however, be distinctly recognised by the microscope in consequence of the dense strata of membrane and mucus-corpuscles. In 1000 parts of this mucus there were contained:

	Analysis 88.
Water	880-0
Solid constituents	120-0
Fat, containing cholesterol	60
Caseous matter, with ptyalin or mucin in solution	13-2
Extractive matters, with lactates and chloride of sodium	120
Albumen, cells, and coagulated mucin	84-0

Gruby found that the mucus secreted during catarrhal affections

¹ [We have at present analyses of only three varieties of mucus, viz. the mucus of the oviduct of frogs, the mucus of the oesophagus of the peculiar species of swallows which build edible nests, and the mucus of the gall bladder. The results differ so much that either animal mucus is a variable mixture of heterogeneous substances, or that different substances at present bear the name of *mucus* in common. The analyses are quoted in Mulder's Chemistry of Vegetable and animal Physiology, p. 240, English translation.]

(slight inflammation) of the mucous membrane of the nose, conjunctiva, fauces, larynx, bronchi, ureters, vagina, and intestinal canal is thicker than the mucus secreted during mere irritation of those membranes; it was thick, tough, lubricous, of a yellowish white colour, and, as it gradually dried, it formed a grayish-yellow elastic mass. It sank in water, unless air-bubbles were entangled in it, and exhibited no change for a considerable time, but ultimately became whiter. With the aid of the microscope, Gruby observed, 1st, a white amorphous mass, not acted on by water (coagulated mucin,) and 2d, round yellowish-white globules, whose number seemed in a direct ratio with the intensity of the yellow colour of the mucus. These cells which were observed in the mucus of the larynx, had eight times the diameter of the blood-corpuscles, were intimately connected with the amorphous white mass, and consisted of a very delicate transparent capsule, that was easily ruptured, of an inner round cell with a nucleus twice as large as a blood-corpuscle, and very many small vesicles one sixth the diameter of the blood-corpuscles, some of which were transparent and some opaque. The large vesicles sometimes contained two inner central cells.

I have also frequently observed these large cells (which strongly resemble the full primary cells described and figured by Henle,¹) in the gray or yellow-streaked gelatinous mucous flocculi which are expectorated during a slight catarrh of the trachea and bronchi, as well as in the thick, tough, yellow nasal mucus that is secreted during a cold. I have represented this bronchial mucus in fig. 16, in which *a a* represent the large cells. Other observers have detected these cells in tubercular matter; it is clear, however, that they occur in diseased mucus, and are not to be regarded as diagnostic of tuberculosis.

Gruby found that the mucus in ophthalmoblenorrhœa, and in the uterine and vaginal discharges of some women after their confinement, is of a deep yellow colour, thready and opaque; it sinks in water and forms flocculi, which, on being stirred, discolour the fluid; but after remaining in the water for some time, they lose their power of communicating their colour to a fresh supply of clear water. This mucus, when dried, forms a yellow, transparent, brittle mass, which continues to burn, when lighted. Under the microscope, a white amorphous mass, insoluble in water, is observed, together with a large number of yellow vesicles of the form and nature of those previously described, some with, and others without a central cell. These vesicles swell in water, the capsule bursts, the enclosed molecules escape, and either become scattered or else accumulate round the unchanged internal cell, and often exhibit for some time the phenomena of molecular motion. Only a few epithelium-cells are observable; those that are present, are full, round, and often closely resemble the large mucus-vesicles. I have likewise observed these epithelium-

¹ Ueber Schleim und Eiterbildung u. s. w. fig. 14.

cells, which I regard as characteristic of a lower stage of development in nasal mucus. (See fig. 14, *d, e, f.*)

The mucus secreted in chronic blennorrhœa of the vagina and bladder is, according to Gruby, of a yellowish white colour, and slightly thready. It quickly renders water turbid, and deposits white flocks at the bottom of the vessel: in other respects it resembles the former varieties of mucus. Under the microscope we observe a small number of yellowish white vesicles, some with a capsule, granular contents, and a central cell, some with merely a capsule and a central cell, and some that are composed of an aggregation of granules, without any capsule whatever.

Gruby found that the lochial discharge,¹ a short time after delivery is of the colour of blood, is possessed of an animal odour, is only slightly thready, and when dried leaves a red pulverizable mass; it consists of hæmato-globulin, fibrin, (probably also albumen,) and vaginal mucus: under the microscope we observe an amorphous thready mass, blood-corpuscles, mucus-vesicles with capsules and aggregated granular molecules, and finally epithelium-cells. Very shortly before delivery we can observe nothing in the vaginal mucus beyond the true mucus-corpuscles (fig. 14, *a,*) and epithelium-cells; but very soon after delivery the large mucus-vesicles, with granular contents (molecular granules) and delicate capsules, make their appearance. Fig. 16, *a*, exhibits these cells, and is copied from the plate in Gruby's work. On the second day after delivery vesicles with a central cell (fig. 16, *b*) are visible, the mucus becomes less dense, the blood corpuscles diminish, and the large mucus-vesicles increase in number. On the third day the reddish lochial discharge contains yellow vesicles with granular contents and central cells. On the fourth day the discharge is considerably less red, and contains white stringy flocculi. On the fifth day the mucus contains grayish white, viscid flocculi, together with white vesicles, eight or ten times the size of blood-corpuscles, which contain only a few, and, in some cases, no granular molecules; these are represented in fig. 16, *c, d.* Between the sixth and tenth days the lochial discharge becomes white, and contains white round vesicles, with finely granular contents, but devoid of a central cell, or the larger molecules. (Fig. 16, *e, f, g.*)

Gruby has shown that the mucus discharged by stool at the commencement of dysentery is clear and stringy, and scarcely different from the mucus secreted in simple diarrhoea; but as the disease becomes more severe, there is a secretion of thick red mucus, consisting of blood- and mucus-corpuscles, resembling the ordinary secretion of inflamed mucous membranes.

I have observed that the mucus secreted during inflammatory affections of the mucous membrane of the respiratory organs is thick, rounded in form, of a white or pale yellow colour, and floats on water. These clots of mucus remain unbroken for a considerable

¹ Scherer's observations on this subject have been already given: see p. 276.

time, but ultimately break up, and sink to the bottom: they then spread out into long tough fibres, which, when observed with the naked eye, have a uniform non-granular appearance: they possess a certain degree of consistency, and feel slippery, in consequence of the mucin which connects the mucus-corpuscles; they are consequently not very easily fixed and broken up by pressure against the sides of the vessel with a glass rod. When examined with the microscope, the white masses of mucus are found to consist of a large number of mucus-corpuscles, and a few epithelium-scales, connected by a delicate granular membrane of coagulated mucin: the yellow clots contain, in proportion to the intensity of their colour, a greater or smaller quantity of the large cells with granular contents, (fig. 16, *a a*.) in some of which a central cell is visible, while in others no cell can be seen. The fluid in which the thick clots of mucus are swimming is slightly clouded by acetic acid, but rendered very turbid by nitric acid: on the application of heat, it becomes white and opalescent; and infusion of galls, and basic acetate of lead yield tolerably copious flocculent precipitates; there is, consequently, a greater quantity of dissolved mucin and albumen present than the water would have extracted from healthy mucus. A quantitative analysis of these floating clots, after being well washed in distilled water, gave the following results.

The numbers are calculated for 1000 parts:

	Analysis 89.
Water	941.75
Solid constituents	58.25
Fat with traces of cholesterol	5.01
Spirit-extract, with lactates and chloride of sodium	11.09
Alcohol-extract	6.95
Cells, mucin, and a little albumen	34.80

In a case of severe bronchitis that recently occurred in Schönlein's clinical wards, the patient expectorated purulent mucus, which, when placed in water, assumed a delicate arborescent form, the ultimate fibrils floating on the water when the slightest motion was communicated to the vessel. When placed in acetic acid, it swelled and became converted into a transparent jelly, and after long digestion almost entirely dissolved; the solution being precipitable by ferrocyanide of potassium. Under the microscope the fibrils resembled coagulated fibrin, and there can be no doubt that plastic lymph was exuded as a consequence of the bronchitis, and expectorated in a coagulated form. [Observations on the sputa in bronchitis and pneumonia may be found in Scherer's 'Untersuchungen,' pp. 93-97.]

Gruby states that the sputa expectorated during the ordinary inflammatory affections of the mucous membrane of the respiratory organs, are, at the commencement of a catarrh, white, transparent, and mixed with gray flocculi; under the microscope they are seen to contain a few round vesicles with granular contents, and numerous epithelium-cells, swimming in a transparent fluid. As the catarrh gets worse, the gray flocculi increase, and become more of a yellow

colour, and the amount of transparent mucus decreases; the coloured flocculi contain numerous cells with granular contents (molecular granules) and a central cell, which are all connected together by very tough mucus. As the inflammation decreases the amount of this globular sputa diminishes, and it assumes a whiter colour.

Purulent Mucus.

If the mucous membranes or the tissues immediately beneath them pass into a state of suppuration, pus becomes mixed with the secreted mucus; in this manner the mucus of the lungs, bladder, intestinal canal, generative organs, &c. may contain pus. When tubercles form in the lungs, they produce, like any other foreign body, a degree of irritation in the surrounding tissue, and an increased degree of mucus is the result. Gruby's observation that the mucus discharged during irritation of the mucous membrane, dependent on the deposition of tubercle, does not differ from the mucus produced during catarrhal affections, is confirmed by Hetterschig¹ and other observers; the secretion of mucus at the commencement of a catarrh is, however, more abundant than that which is produced by the irritation of existing tubercles.

The quantity of expectoration increases with the more extended deposition of tubercle, until softening commences; the tubercular matter is then expectorated, and, in consequence of the inflammation that occurs, pus is secreted by the walls of the cavity thus produced, and in this manner gets mixed with the sputa.

The purulent expectoration of persons with tubercular phthisis is easily distinguished by the experienced practitioner from healthy sputa,² and with tolerable certainty from diseased mucus, nor can there be any doubt regarding its nature while tubercular matter is being discharged from a vomica, but the transition from diseased into healthy purulent mucus is so slight and imperceptible, that it is hardly possible to detect the first traces of pus that are mingled with the mucus; for although, as I shall presently show, their general physical and chemical relations are perfectly sufficient to distinguish pure pus from pure mucus, we have no means of determining with certainty the presence of a little pus in mucus, or the presence of a little mucus in pus.

Purulent mucus from the lungs contains much less mucin than normal or diseased mucus,³ and consequently the mucous clots have not the toughness, lubricity, and consistence observed in mucus, unmixed with pus: in fact they have a decided tendency to dissolve. Purulent mucus sinks more quickly in water than the normal secretion, partly in consequence of the fewer air-bubbles that are enclosed,

¹ De Inflammatione ejusque exitu diverso. Trajecti a. R. 1841, p. 176.

² [Dr. Wright's papers on Expectoration (recently published in the Medical Times) may be consulted with advantage.]

³ [This is perfectly consistent with the observation of Eichholtz, that the pyin (or mucin) varies inversely with the pus-corpuscles.]

(on account of slighter tenacity of the fluid medium of communication, and the comparative facility with which they escape,) and partly in consequence of the greater amount of albumen in the fluid, and its higher specific gravity. If the secretion is composed of nearly equal parts of mucus and pus, it sinks rapidly to the bottom, and forms small definite tough clots: the masses may easily be broken up by means of a glass rod, and can often be separated by mere shaking: they have not so uniform an appearance as the healthy or morbid clots of mucus which float on water, but to the naked eye they appear finely granulated or gritty, since, in consequence of the deficiency of the connecting medium—the mucin, the cells of the secretion are not so closely associated.

When there is only a small amount of pus in the globular sputa during phthisis, it separates from the mucus on being placed in water; the pus at once sinks, and while the mucus is still floating on the surface we may observe long dependent viscid fibres, at the extremities of which, white or yellowish granular particles of pus may be noticed.

Phthisical sputa deposit a whitish granular sediment at the bottom of the vessel, while masses of mucus are still floating on the surface of the water. A microscopic examination of the sediment shows that it consists of cells, which closely resemble mucus-cells, especially when they have been in the water for any time: since, however, the cells of purulent sputa come in contact with the water more readily in consequence of the smaller quantity of the connecting medium, mucin, they swell and become larger than the mucus-corpuscles, after they have been for only a short time in the water: the capsules become transparent and vesicular, the granular appearance vanishes, and one, two, three, or even more nucleoli, become visible: the capsules of many of the cells burst, and the nuclei swim about in a state of freedom, in the same manner as we observe in mucus that has been long under water. A microscopic representation of these pus-corpuscles is given in fig. 17. The water in which purulent mucus has been placed differs materially from that in which normal or diseased mucus has been swimming. It is either nearly clear and colourless, or else of a pale yellow tint, is viscid, and is slightly clouded by acetic acid, but is rendered white and opaque by the addition of nitric acid: the action of heat likewise renders it turbid, and coagulates a considerable quantity of albumen, which separates in the form of flocculi.

Infusion of galls and basic acetate of lead cause dense precipitates; in fact, the addition of the former sometimes completely thickens the fluid.

The quantity of albumen is therefore much larger than in simply diseased mucus.

Pus.

Violent irritation of the mucous membrane may produce suppuration and cause a secretion of pus in place of the ordinary mucous secretion; thus it appears that the formation of pus is dependent on the very same process which, when acting with less intensity, first increases the secretion of mucus, and subsequently renders it abnormal. Pus, however, also forms in other and distinct parts of the body, after pre-existing congestion and inflammation, as for instance in cellular tissue, skin, muscular tissue, &c., and appears to differ both in its physical and chemical characters in accordance with the seat of its formation and the length of time it has remained in the organism.

Genuine pus usually occurs as a rather thick fluid, viscid, but capable of separating in drops, somewhat like cream, of a whitish-yellow, yellow, or greenish-yellow colour, and of a faint but not disagreeable animal odour. It may be slightly acid, slightly alkaline, or neutral; when mixed with water it sinks rapidly to the bottom, but on stirring, it forms an emulsive fluid, from which a sediment of pus-corpuscles is soon again deposited.

When examined under the microscope, pus appears (like mucus) to consist of a clear fluid in which small, round, and occasionally oval corpuscles are swimming, the quantity of which seems to be in a direct ratio with the thickness of the pus. Pus- and mucus-corpuscles so closely resemble each other, that no distinctive mark, founded either on their form or on their chemical relations, has hitherto been discovered. The size of the corpuscles is nearly the same; in tough pus they are somewhat smaller, and in thin watery pus, rather larger than the mucus-corpuscles: oval corpuscles, which may be often seen in mucus, and are probably dependent on the viscosity of the secretion, are rarely found in pus.

In fresh pus the corpuscles are white, opaque, and apparently granular; when treated with water they become rather larger, lose, in some degree, their granular appearance, and soon give indication of an internal nucleus. With acetic acid they behave exactly in the same manner as mucus-corpuscles; the capsule becomes transparent and perfectly clear, and the nuclei become visible. The minuteness of the nuclei depends on the number that occur in the pus-corpuscle; we seldom find more than five, usually two or three. With the aid of a good light we may observe that many of these nuclear-cells possess a capsule and nucleolus. Pus-corpuscles dissolve rapidly in free potash, and more slowly in free ammonia. Other reagents produce the same effects as on mucus-corpuscles.

A very small quantity of dissolved alkali, such, for instance, as occurs in the blood, seems to exert a rapid influence on the form of the pus-corpuscle; for I have seen, in the blood of persons who have died from phlebitis, a large quantity of pus-corpuscles, (some isolated, and others swimming in heaps,) which were very pale, larger than usual, and of an irregular and tuberculated outline.

The liquor puris, or fluid in which the corpuscles are swimming, is transparent, and usually of a pale yellow colour; it contains so large an amount of albumen in solution, that, on the application of heat, it becomes perfectly white, and deposits innumerable flocculi of coagulated albumen. The large amount of albumen associated, moreover, with no trifling quantity of fat, distinguishes the liquid portion of pus from the tough and consistent fluid of mucus, and indicates the affinity between the liquor puris and lymph. The fat is partly combined with alkalies, and free fat-vesicles cannot always be detected. The largest portion of the fat is apparently contained in the pus-corpuscles; and, (as I have already observed when speaking of mucus,) the nuclei, if not composed altogether of fat, in all probability contain a very considerable proportion of that constituent; for, after the addition of acetic acid, I have frequently observed a greater or less number of fat-vesicles in pus which previously exhibited no traces of them. The fatty matter of pus contains cholesterin, and, according to the observations of Güterbock, develops ammonia while burning; hence the presence of a nitrogenous fat may be assumed. The liquor puris is usually rendered turbid by acetic acid; the effect may vary from an almost imperceptible cloudiness to a decided precipitate; if the pus has an acid reaction, this test produces no change. There can be no doubt that the substances which are precipitated in this manner from the liquid parts of pus and mucus are analogous, and that the deposit which occurs in the liquor puris, after the addition of acetic acid, is either actual mucin held in solution by an alkali, or a substance scarcely differing from it,—pyin.¹

The fluid portion of pus, like that of mucus, contains extractive matters and salts; the former occur in larger quantity in pus than in normal mucus. According to Güterbock,² the salts consist of chlorides, carbonates (arising from the decomposition of lactates,) sulphates, and phosphates; the two latter doubtless arise in part from the oxidation of phosphorus and sulphur during the incineration of the albumen. The bases are potash, soda, lime, magnesia, and traces of iron. According to Martius,³ the pus-corpuscles contain a little phosphate of lime and silica; others have placed the ammonia-salts amongst the constituents of normal pus.

The liquor puris is strongly precipitated by the mineral acids, metallic salts, and tannic acid, in consequence of its containing albumen, mucin, and extractive matter: after the addition of a little dilute hydrochloric or acetic acid, it is also precipitated by ferrocyanide of potassium. Small quantities of tubercle occur in the purulent sputa of phthisical patients, in the form of little, white, yellow, or brownish-yellow, irregular, and moderately soft masses, varying in dimensions from the size of a grain of sand to that of a small hemp-seed; they are usually enclosed in mucus, and sink rapidly in water.

¹ See note, page 350.

² Annalen der Pharmacie, vol. 24.

³ De pure et granulatione, p. 18.

I have never observed many of these masses in the sputa; on the contrary, their occurrence was only very rarely noticed, considering the great number of phthisical patients in the Berlin hospital. The irregular fragments of tubercle appear to the eye to be of a caseous nature; but, after being moistened with water, submitted to pressure between two pieces of flat glass, and placed under the microscope, they seem to be composed of an amorphous, finely granular, opaque, yellow matter, in which there are a varying number of fat-vesicles and some minute ramifying tubuli or fibrils, as in fig. 18. We sometimes meet with peculiar forms in tubercle, which, doubtless, belong to the tissue or vessels of the lung; they have likewise been observed by Gruby, and I have represented several of them in fig. 19.

Gruby has observed peculiar corpuscles in tubercle which I have hitherto sought for in vain, both in tubercular lungs and in expectoration, and which he regards as characteristic of that morbid deposit. He describes them as lenticular, round, or oval, whitish-yellow corpuscles, with concentric rings, their lamellae being arranged in the same manner as those of an onion, and their size being from two to ten times as large as a pus-corpuscle; they are frequently jagged at the edges, dissolve easily in caustic potash, and become distended in nitric acid and a solution of nitrate of silver.

It appears from the preceding observations that pus consists of two distinct portions; namely, of a fluid, the liquor puris; and of corpuscles swimming in this fluid and insoluble in it. The corpuscles are surrounded by a capsule, which becomes tumid in water, is soluble in free potash and is reduced by ammonia to a thick viscid jelly, dissolves on prolonged gentle digestion, and is doubtless composed of mucin. Of the nature of the contents of the corpuscles lying between the nucleus and the capsule we know nothing; the nucleus probably consists of albuminous matter and fat. The liquor puris contains albumen, fat, pyin or dissolved mucin, extractive matter, and salts. For the quantitative analysis of these substances I adopted the same method as in the analysis of mucus. (See page 351.)

Güterbock's quantitative analysis of pus was made in the following manner: Pus was boiled with anhydrous alcohol, and filtered while still hot; on cooling, the fat separated. The clear alcoholic solution was evaporated, and the residue treated with water, which dissolved the extractive matter and some free acid, but left undissolved the small portion of fat that had escaped removal by the alcohol. The portion insoluble in boiling anhydrous alcohol was freed from the spirit by gentle evaporation, and treated with water which took up pyin, and some albumen probably combined with soda. The insoluble portion consisted of coagulated albumen and pus-corpuscles: the salts were determined by the incineration of a separate quantity of pus.

Normal pus has been analyzed by Güterbock, Valentin,¹ G. Bird,²

¹ Valentin's Repertorium, 1838, p. 307.

² Ancell's Course of Lectures on the Physiology and Pathology of the Blood, and the other animal fluids. The Lancet, 1839-1840, p. 745.

Wood,¹ [Von Bibra,² and Wright.³] The discrepancies observable in their results are probably due in a great measure to the different modes of analysis which they adopted. The pus analyzed by Güterbock was taken from a mammary abscess. That which was analyzed by Valentin came from a large abscess in a man's thigh; it was of a yellow colour, neutral, of a balsamic odour, and had a specific gravity of 1027. Wood analyzed pus from the hand of a young man, and from abscesses in the cheek and breast of a woman. The analysis of the mixture is given below. The pus analyzed by Golding Bird was taken from a psoas-abscess, and had a specific gravity of 1040.9.

<i>Güterbock.</i>					
Water	-	-	-	-	861.0
Solid constituents	-	-	-	-	139.0
Fat, soluble only in hot alcohol	-	-	-	-	16.0
Fat and extractive matter, soluble in cold alcohol	-	-	-	-	43.0
Albumen, pyin, and pus-corpuscles	-	-	-	-	74.0
Loss	-	-	-	-	6.0
<i>Valentin.</i>					
Water	-	-	-	-	883.78
Solid constituents	-	-	-	-	116.22
Cholesterin	-	-	-	-	11.86
Oleate of soda, olein, and chloride of potassium	-	-	-	-	10.02
Stearin	-	-	-	-	6.65
Coagulated albumen and fibrin	-	-	-	-	79.78
Fluid albumen and chloride of sodium	-	-	-	-	19.34
<i>Golding Bird.</i>					
Water	-	-	-	-	898.00
Solid constituents	-	-	-	-	102.00
Fat	-	-	-	-	5.00
Water-extract, with alkaline lactates	-	-	-	-	8.00
Albumen	-	-	-	-	75.75
Chlorides of sodium and potassium, with carbonates	-	-	-	-	5.75
Phosphates of lime and iron	-	-	-	-	7.50
<i>Wood.</i>					
Water	-	-	-	-	857.15
Solid constituents	-	-	-	-	142.85
Cholesterin	-	-	-	-	1.57
Oleate of soda	-	-	-	-	10.91
Extractive matter, with chloride of sodium and other salts	-	-	-	-	8.34
Albumen	-	-	-	-	19.09
Animal matter, with the properties of ptyalin and glutin	-	-	-	-	16.57
Fibrous matter, with phosphate of lime, peroxide of iron, and sulphur	-	-	-	-	86.37

The salts amounted, according to Güterbock, to 5.7% of the solid residue, namely, to 5 soluble in water, (consisting, for the most part, of chloride of sodium with small quantities of phosphate, sulphate, and carbonate of soda, chloride of potassium, and chloride of calcium,) and 0.7 soluble only in nitric acid, and composed of the phosphates of lime and magnesia, carbonate of lime, and a trace of peroxide of iron.

Valentin estimated the salts at 5.32% of the solid residue, of which

¹ De puris naturâ atque formatione disq. phya. Berlin, 1837, p. 10.

² Unters. über einige verschiedene Eiterarten. Berol. 1842.

³ Medical Times, Jan. 11, 1845.

4.7 were soluble in water, (chloride of sodium with traces of the sulphates of potash, soda, and lime, and carbonates of potash and soda,) and 0.62 insoluble in water, (phosphates, sulphate, and carbonate of lime.)

[A large number of analyses of pus and purulent sputa have been made by Von Bibra. We select the three following:

	Pus from an abscess in the cheek.	Ditto in the chest.	Ditto in the neck.
Water	769	852	907
Albumen and pus-corpuscles	160	91	63
Fat	24	33	9
Extractive matter	19	29	20

Several analyses of pus have been made by Dr. Wright. The three following analyses will serve as specimens:

	Pus from a vomica.	Pus from a pus abscess	Pus from a mam- mary abscess.
Water	894.4	885.2	879.4
Fatty matter	17.5	28.8	26.5
Cholesterin	5.4		
Mucus	11.2	6.1	
Albumen	68.5	63.7	83.6
Lactates, carbonates, sulphates and phosphates of soda, potash, and lime	9.7	13.5	8.9
Iron	a trace.		
Loss	3.3	2.7	1.6

Nasse¹ has published two analyses, one of serum and pus, and the other of serum and blood, with the view of comparison. The following are his results:

	Serum of pus.	Serum of blood.
Water	890.00	906.5
Solid residue	110.00	93.5
Organic constituents	92.58	85.7
Chloride of sodium	12.60	4.6
Carbonate of soda	2.22	1.4
Phosphate of soda	0.32	0.9
Sulphate of soda	0.18	0.2
Phosphate of lime	1.20	0.7
Carbonate of lime	0.90	

I made an analysis of pus which was discharged with the urine by a servant-girl with phthisis vesicæ: it was rather tough, of a reddish colour, in consequence of a little blood that was mixed with it, and quickly sunk to the bottom of the vessel, after the urine had been stirred. Before examination, it was washed with water and evaporated to dryness on the water-bath. There were contained in 100 parts :

	Analysis 90.
Fat containing cholesterin	5.20
Albumen, with phosphate of lime	40.20
Pyin, casein or globulin, and some extractive matter	17.00
Hæmatin, urea, alcohol-extract, and lactate of soda	10.60
Spirit-extract, with chloride of sodium, lactates, and phosphates	1.30
Water-extract, with phosphates and sulphates	13.60

¹ Simon's Beiträge, p. 338.

Pus secreted by the synovial membrane of the knee-joint is composed, according to Wood,¹ of water, 888·1; cholesterin, 4·0; oleate of soda with soda, and potash-salts, 22·4; animal matter and chloride of sodium, 30·2; a substance resembling glutin, 15·2; albumen, 40·1. Martius² analyzed a purulent fluid obtained from a patient with empyema, from whom 153 ounces of matter were evacuated. It was tolerably thick, of a dirty greenish-gray colour, devoid of odour, and had a slightly acid reaction: when heated it swelled very much; it sunk to the bottom in water, but on agitation the two fluids mixed. On boiling it, some floccules separated themselves, but no coagulation took place; the fluid, after filtration, was of the colour of sherry, and had a specific gravity of 1111·5.³ The principal constituents were water, fat, albumen, extractive matter, glutin, potash, soda, magnesia, lime, ammonia, phosphoric, hydrochloric, and lactic acids. Koch⁴ analyzed pus with very similar results: it is not stated from whence the pus was obtained; it consisted of water, albumen, extractive matter, mucus, and pus-corpuscles. In addition to the salts found by Martius, Koch detected carbonates and sulphates, resulting from the action of heat on lactic acid and sulphur during incineration.

John⁵ describes pus from the ovary of a consumptive woman, as a greenish fluid, of the consistence of a liniment, and with a peculiar odour; it contained albumen, a substance resembling that substance, resin, gelatinous matter, and the ordinary salts, together with carbonate of ammonia.

Chevallier⁶ found in pus from a syphilitic bubo in the axilla, ten days after its formation, albumen, gluten, chlorides of potassium, sodium, and ammonium, with some sulphates; it was viscid, of a blood-red colour, of a sickly odour, neutral, and coagulated on heating. The fluid from an abscess, in a case of spina bifida, contained, according to Bostock, water, 978; chloride of sodium, 10; albumen, 5; mucus, 5; gelatin, 2; and a trace of lime. The fluid which Gruby obtained from pustules in smallpox, twenty or thirty hours after the commencement of the eruption, had an alkaline reaction; it contained some white, nearly transparent molecules, and round caudate infusoria. On the third day pus-corpuscles were observable, and subsequently became more numerous.

On the fifth, sixth, eighth, and ninth days after the commencement of the eruption the pustules contained a thick yellow fluid, which had a slightly alkaline reaction, and contained numerous yellow pus-corpuscles, the capsules of which readily burst.

Tremoliere describes the contents of a well conditioned pustule as yellow, turbid, and with an oily appearance. The smell and taste of this fluid were unpleasant, its specific gravity was 1031, and it consisted, according to his statement, of fibrin, mucus, chloride of sodium, sulphate of potash, and phosphate of lime. Gruby found that

¹ Op. cit. p. 21.

² This must be an error of observation or a misprint.

³ Chemische Untersuchungen, vol. 2, 1812, p. 120.

⁴ Annal. der Pharm. 24, p. 79.

⁵ Diss. inaug. Berol. 1825.

⁶ Gmelin's Chemie, vol. 2, p. 1395.

the fluid in the pustule on the seventh day was transparent; it contained white, nearly spherical vesicles, which appeared wrinkled on one side.

Vogel has made some important observations regarding the modifying influence of tissue, constitution, &c., on the nature of pus.

Pus from the cellular tissue is usually the purest, pus from mucous or serous surfaces being too thin and fluid, and containing in one case an admixture of mucus, in the other of serosity. Pus from the liver is pulaceous, thick, and of a brownish-red colour. On allowing it to stand for some time, a dense, thick, and reddish matter separates from the white pus. Pus from the kidneys is usually rather fluid, of a whitish-yellow colour, and saltish. Pus from the urinary bladder may be either fluid or tough, and varies in colour from a yellow to a dirty brown-red tint; it frequently also has an ammoniacal odour. Pus from the bones is blackish, or white with black specks; it has an odour and taste of phosphorus. Syphilitic pus is of a yellow or yellowish-green colour; it possesses a nauseous smell, and a sweet but sickly taste. Scrofulous pus is caseous, very fluid, grumous, and sometimes resembles coagulated milk; according to Gendrin, it contains more soda and chloride of sodium than ordinary pus; according to Preuss, it contains casein, like tubercular matter. Rheumatic and arthritic pus are very similar; for the most part very fluid, irritative, and corrosive. I have examined the dried residue of the liquor puris of an arthritic person; it was of a grayish-yellow colour, contained no membranous shreds, could be easily pulverized, and exhibited no appearance of crystals when examined under the microscope. On heating it with nitric acid, I obtained, after the evaporation of the acid, and more strikingly on the addition of ammonia, a brilliant purple colour, indicating the presence of uric acid beyond a doubt. On triturating this substance with water I obtained a pulpy mass, which, when examined under the microscope, was found to contain numerous epithelium-cells and pus-corpuscles, but no crystals of uric acid. Alcohol extracted 5·4% of fat, consisting chiefly of margaric and oleic acids, with a little cholesterol; boiling water took up 52·6%, of which a little fat, extractive matters, with hydrochlorate of ammonia and lactate of soda, were soluble in anhydrous alcohol; and chloride of sodium, extractive matter, and albuminate of soda in spirit. The remainder was washed with cold water, (which extracted very little,) and was then dissolved in a faintly alkaline solution. On the addition of hydrochloric acid to this alkaline solution, crystals of uric acid were deposited, and some albumen thrown down from the albuminate of soda: the acid solution then contained hydrochlorate of ammonia and chloride of sodium. The portion insoluble in water yielded on incineration 5% of ash, consisting of earthy phosphates, with a little peroxide of iron and carbonate of soda; the dried residue of the liquor puris yielded, however, 10% of ash, composed of carbonate of soda, a little phosphate of soda, carbonate and phosphate

of lime, a little chloride of sodium, and traces of peroxide of iron. It contained in 100 parts:

	Analysis 91.
Portion insoluble in water	47·4
Fat	5·4
Alcohol-extract, with hydrochlorate of ammonia and lactate of soda	4·9
Spirit-extract, with chloride of sodium and albuminate of soda	17·5
Uric acid and albumen, combined with ammonia and soda	17·2

The amount of the individual salts was not determined.

I have received, through the kindness of Dr. Piutti, of Elgersburg, two small flasks filled with a white fluid discharged from an abscess on the foot of a gouty patient, who had been trying the water-cure. On standing, the fluid threw down a copious white sediment, the supernatant liquid portion having a reddish tint. When shaken, innumerable crystals might be observed with the naked eye, which, under the microscope, exhibited an acicular form; a few pus-corpuscles were also present. The crystals, after being carefully washed, so as to remove all extraneous matter, formed, when dry, a white powder, and when incinerated on platinum foil, left a white fused ash, consisting of carbonate of soda. The white crystalline mass, when warmed with nitric acid, yielded the deep purple tint indicative of uric acid. On digesting a portion with dilute hydrochloric acid, a large number of rhombic tablets of uric acid appeared on cooling. The hydrochloric acid solution yielded, on gentle evaporation, crystals of chloride of sodium. Hence the white acicular crystals consisted of urate of soda. The red supernatant fluid contained a few corpuscles, a large quantity of albumen, and some haemato-globulin.

Scorbutic pus is thin, ichor-like, of a bad odour, often mixed with blood, and soon becomes putrid. Cancerous pus possesses a very peculiarly fetid odour, and appears very frequently to contain sulphurated hydrogen and ammonia.

Pus sometimes contains infusoria; thus R. Wagner¹ has observed minute ciliated animalcules, in some slight degree resembling pus-corpuscles, in pus taken from cancer of the lip; they appeared to be the *colpoda cucullus*. Valentin has also observed infusoria in the purulent fluid of carcinoma. Donne² has observed the *vibrio lineola* in the pus from chancres and gonorrhœa: he found other forms of infusoria in the pus from syphilitic vaginitis; they were twice the size of the blood-corpuscles, with a round elliptic body, considerably prolonged anteriorly; he proposes for this animalcule the name of *tricomonas vaginalis*.

Ichor.

When pus begins to undergo decay, or is secreted from malignant or carcinomatous growths, or when mortification comes on in conse-

¹ Valentin's Repertorium, p. 119.

² Recherches microsc. sur la nat. du Mucus, etc. Paris, 1837.

quence of the depressed state of the vital powers, it becomes thin and discoloured, (being often of a brown or reddish tint,) and emits a fetid odour: it is then termed ichor. Ichor frequently contains no pus-corpuscles, or only a very few, and those partially broken: it is of a blood-red colour, but does not always contain blood-corpuscles, the red colour being apparently due to their solution in the putrid and decomposed fluid. From the odour we may infer the presence of hydrosulphate of ammonia. Vogel examined some ichorous pus from a sore in the foot of a rheumatic patient; he found perfectly normal pus-corpuscles in it, and it only differed from normal pus in its greater fluidity.

Pus of animals.

I have analyzed pus from a lymphatic gland in a horse. There were contained in 1000 parts:

	Analysis 92.
Water	976·00
Solid constituents	24·00
Fat, containing cholesterol	1·68
Water-extract and caseous matter	1·26
Spirit-extract, with lactates, and chloride of sodium	2·94
Albumen, cells, phosphate and sulphate of lime, and traces of iron	17·64

Göbel¹ has analyzed pus from the uterus of a mare; it was a thick fluid, of a whitish-yellow colour, opaque, of specific gravity 1079, and had a faint animal odour: it was neutral, and coagulated on the application of heat. It contained, water, 913·3; albumen, 7·2; gelatinous non-coagulable animal matter, 9·4; chloride of sodium, lactate and sulphate of potash, phosphates of lime and magnesia, protoxide of iron, and silica, 5·3. Dumas analyzed pus from the frontal sinus of a mule: it reddened litmus paper, formed an emulsion with cold water, and when heated to 158°, yielded a granular coagulum. It contained 17·9% of solid constituents, of which 16·5 were albumen; the remainder consisted of extractive matter, free lactic acid, phosphates and sulphates.

On the formation of mucus and pus on mucous membranes and on the detection of pus in mucus.

It seems to be now almost generally admitted that the distinctions between pus and mucus are to be sought for, not in the morphological character or chemical relations of their respective corpuscles, but rather in the chemical peculiarities of the fluid portions of these secretions.

It has been already shown that the fluid of mucus contains a large quantity of dissolved mucin, while no albumen, or, at the most, a mere trace, is present: on the other hand, the fluid of pus is rich in albumen, and contains only a very small quantity of dissolved mucin. Hence,

¹ Schweigger's Journal, vol. 34, p. 407.

if it were proved that normal mucus never contains albumen, we might conclude that all mucus which gave indications of the presence of that substance was purulent. We should then also arrive at the conclusion that most persons, on the slightest irritation of the mucous membrane, secrete purulent mucus. In this manner we should have to agree with Vogel that normal mucus contains only epithelium, and that any secretion of mucus-corpuscles indicates an admixture of pus.

To the physician the detection of traces of pus in mucus is a point of little importance; it is of much more consequence to be able to decide from the sputa whether suppuration of the parenchyma of the lungs or of other tissues has actually commenced. The point is one of very great difficulty, in consequence, as has been previously observed, of the imperceptible changes that mucus undergoes in its transition from the normal secretion into pus.

My own observations, as well as those of others, lead me to concur in the view that Henle¹ has developed in his essay on the Secretion of Pus and Mucus, in which he distinctly and ingeniously points out the analogous phenomena between mucous membranes and the external skin. The mucous membranes are covered with several layers of epithelium, and in the ordinary course of secretion the more recent and inferior layer of cells projects against the superior and older cells which constitute the existing epithelium. The inferior cells themselves gradually become epithelium, and, in their turn, are thrust out and supplanted by still deeper cells. As the fluid portion of the mucus is secreted at the same time, it evidently cannot be regarded as the cytoplasm of these cells, but must be looked upon as effete, and no longer essential to the formation of mucus-corpuscles; the albumen for their nutrition having been extracted from it during the progress of their development towards actual epithelium, and only mucin (the product of their metamorphosis left in its stead.)

As the secretion is increased by irritation of the mucous membrane, it follows either that such epithelium as is thrown off in the normal state is then not formed at all, or else that it is only secreted imperfectly, and consequently we meet with cells in every state of development under these circumstances. These changes in the epithelium lead to corresponding variations in the fluid portion of the mucus, for if a normal stratum of epithelium is no longer formed, that is to say, if the deeper layers throw off the superior cells before they have arrived at maturity, the changes impressed on the fluid must be different from those which it would undergo during the ordinary secretions of healthy mucus. It is impossible that all the nutritious matter of this fluid can be consumed by these immature cells, and we consequently find in it, under these circumstances, a greater or less quantity of albumen and fat, two substances which universally yield a cytoplasm for the higher development of cells.

If an increased secretion of mucus takes place on a mucous membrane which possesses only a single layer of epithelium, (either the

¹ Hufeland's Journal, May, 1836.

cylinder or the ciliated variety,) the mucus-corpuses appear immediately after the epithelium has scaled off. The transition of the mucus-corpuses into epithelium-cells is not observed so well in this instance, as when there is a profuse secretion from a surface possessing several layers. These transitions and various stages of development lead us to the conclusion that the mucus-corpuses represent the first stage of formation of the epithelium-cells, into which they would ultimately have been converted if they had not been thrown off too early, and, further, that the different forms of epithelium-cells are in their primary state identical with one another.

The same elements are likewise recognised, according to Henle, in other tissues, in the ganglia of nerves, in the brain, in the contents of the Graafian vesicle around the ovum, in the parenchyma of the liver, and in the blood-formative glands, (the spleen, thymus, and thyroid.) These cells occur also in the blood, where I have termed them chyle-corpuses; they probably represent the blood-corpuse in a preparatory stage of development.

If we suppose the secretion of mucus to be still further increased, the mucous membrane will produce only these primary cells, which cannot be distinguished from pus-cells, with which, in fact, they are identical. Whether the secreted fluid is to be regarded as pus, mucus, or purulent mucus, depends on the quality of the liquid that is secreted with the cells. If it contains much mucin, the fluid must be regarded as mucus; if there is no mucin in it, or only a small quantity, but on the other hand much fat and albumen, it must be regarded as pus; while if all three are contained in the fluid, it must be regarded as purulent mucus. In a very diseased state of the mucous membrane the fluid may even contain fibrin, and thus resemble plastic lymph. Henle¹ has observed this in one instance. We may consequently observe the various stages of transition from plastic lymph to the normal fluid of mucus (containing mucin, but no albumen,) in the same manner as we can trace the epithelium-cells gradually downwards till they assume the form of primary cells.

The following conclusions are all that we are entitled to deduce from the previous observations:

(1.) Pure mucus floats on water for a considerable time if air-bubbles are entangled in it; pure pus sinks rapidly to the bottom; purulent mucus swims if it contain air-bubbles, but allows the pus to deposit itself; the deposit frequently takes place in the form of pendent fibres. If pure mucus contain no air-bubbles, it sinks.

(2.) Pure mucus, lying in water, appears as a homogeneous, streaked, vesicular, viscid, and tenacious mass, of a white or whitish-yellow colour, and yielding readily to pressure. Pure pus forms a stratum at the bottom of water, of a white or greenish-yellow colour, and sometimes tinged with blood; by agitation it is diffused through the water, and in a short time again sinks to the bottom. Purulent mucus forms streaked, vesicular, often discoloured masses, or mucous

¹ Hufeland's Journal, 1836, p. 21.

sediments; they are easily diffused through water, and have a granular, non-homogeneous appearance.

(3.) Pure mucus imparts no albumen or mucin to water; mucus which is mixed with much saliva does, however, render water a little albuminous; pure pus communicates a large amount of albumen to water, and purulent mucus imparts a quantity of albumen proportionate to the amount of pus.

None of what have been termed the "pus tests" are calculated, in my opinion, to detect minute quantities of pus in mucus, and no test is requisite to distinguish pure mucus from pure pus, or to recognise a large quantity of pus in mucus.

CHAPTER VI.

SECRETION OF THE EXTERNAL SKIN.

Sweat. (Sudor.)

THE sudoriparous glands continuously secrete a very considerable amount of watery fluid, which, in consequence of the extent of surface over which these glands are distributed, usually passes off directly in the shape of vapour, leaving behind, however, on the skin, its various solid constituents, mixed with the secretion of the sebaceous glands. It is only under the influence of active exercise, high external temperature, or certain forms of disease, that the secretion is elaborated in such quantity as to stand in drops on the skin, instead of being carried off as insensible vapour; it is then termed *sweat*.

Attempts have been made by Sanctorius, Dodart and Reil, and more recently by Lavoisier and Seguin, to determine the quantity of fluid which escapes from the skin within a certain time, in the form of vapour. Seguin found that, on an average, 18 grains of fluid were discharged in a minute by the skin and lungs; the former exhaling 11 and the latter 7 grains. The minimum exhalation from both sources amounted to 11 grains; the maximum, in a state of rest, to 32 grains in a minute. From these data the maximum of matter lost by the body through the skin and lungs in 24 hours, would amount to 5 pounds, and the minimum to 1 pound, 11 ounces, and 4 drachms. Taking the average of 11 grains in the minute, the whole quantity would amount to 29 ounces of fluid.

The amount of solid constituents carried off with the fluid, is comparatively very small, and does not exceed 7 or 8 scruples in the 24 hours: all the rest is mere water, with some carbonic acid, and perhaps some nitrogen.

The solid constituents of the sweat consist of a mixture of salts and extractive matters, of which the latter preponderate; the principal ingredient of the salts is chloride of sodium.

I have on several occasions collected and analyzed the sweat of persons in the vapour-bath; it is, however, always mixed with more or less water condensed on the body from the vapour of the bath. The sweat collected in this manner from the arms and face was a turbid, rather dirty-looking fluid, which, after standing for some time, deposited gray floccules, recognisable under the microscope as epithelium-scales, for the most part broken and in fragments. The filtered sweat had in one instance a specific gravity of 1003, in another of 1004; it was slightly acid, which appears to be the ordinary reaction of normal sweat; in the course of 24 hours it became neutral, and on holding over it a rod moistened with hydrochloric acid, a slight cloud was observed.

On evaporation of my own sweat, as well as that of another healthy man, the peculiar smell of the axilla was observed, and an odour of ammonia developed; the presence of this substance was also indicated by the test to which we have just referred. On evaporation to dryness, the odour of extractive matter became perceptible. On triturating a portion of the residue with free potash, ammonia was developed; on the addition of sulphuric acid to another part, sulphurous acid was first given off, and afterwards a marked odour of acetic acid. In one instance the odour of butyric acid was so clearly associated with that of acetic acid, as to leave no doubt of its presence.

On boiling the dried residue of sweat with ether, a small quantity of fat is taken up, which may be isolated by evaporating the ether, and possesses the peculiar odour of sweat. Alcohol, on being then added to the residue, becomes of a pale yellow colour, and is rather strongly precipitated by tannic acid and acetate of lead,—indications of the presence of alcohol-extract. On evaporation of the alcohol, chloride of sodium crystallizes in cubes, and in addition to these cubes, which constitute the greater part of the salts, and many of which have octohedral surfaces, there are also long prisms, plates, and fern-like crystalline clusters of hydrochlorate of ammonia; the latter, especially, is very abundant in sweat that has stood for some time. On treating a portion of the residue of the salts with sulphuric acid, there is extricated in the first place some hydrochloric acid in a state of vapour, and subsequently a decided odour of acetic acid. If a portion of the residue is incinerated, the ash effervesces on the addition of hydrochloric acid. On dissolving out the chlorides with alcohol, and adding bichloride of platinum, we obtain a slight yellow precipitate. The residue is soluble in water, with the exception of some gray flocculi, and on the addition of tannic acid this aqueous solution yields a precipitate, which shows that the sweat contains water-extract. The solution also contains a small quantity of lime, but hardly a trace of phosphoric acid, and only once, in several trials, was there a faint indication of sulphuric acid. When the whole residue of the sweat was incinerated, the amount of phosphate of lime was much larger, and a considerable quantity of sulphuric acid, as well as traces of peroxide of iron, were always perceptible.

It is true that these are superficial and merely qualitative investigations; they are, however, sufficient to establish the existence, in normal sweat, of

1. Substances soluble in ether: traces of fat, sometimes including butyric acid.
2. Substances soluble in alcohol: alcohol-extract, free lactic or acetic acid, chloride of sodium, lactates and acetates of potash and soda, lactate or hydrochlorate of ammonia.
3. Substances soluble in water: water-extract, phosphate of lime, and occasionally an alkaline sulphate.
4. Substances insoluble in water: desquamated epithelium, and (after the removal of the free lactic acid by alcohol) phosphate of lime, with a little peroxide of iron.

The results of the investigations of other chemists coincide generally with these conclusions of mine. Berzelius infers from his analyses of sweat that collected in drops on the forehead, that it contains in solution the same substances which occur in a dissolved condition in the acid fluid of muscular flesh, together with an excess of chloride of sodium. The most comprehensive analyses of sweat have been made by Anselmino.¹ He enclosed the naked arm in a glass cylinder, and collected the sweat that had exhaled during several experiments: in the course of five or six hours a table-spoonful had condensed. A portion was heated with sulphuric acid, evaporated, and caustic potash added to the residue; by this means the presence of ammonia was established beyond a doubt. On digesting another portion with oxide of lead, and moistening the dried mass with sulphuric acid, vapours of acetic acid were developed. A third portion, which was treated with lime water, became turbid, in consequence of the presence of carbonic acid. For the purpose of determining the solid constituents, Anselmino made use of sweat that had been collected by clean sponges from the vapour-bath; it was turbid, and had a strong though by no means a constant odour. After the distillation of a portion of the filtered liquid in the steam-bath, acetate of ammonia was found in the fluid that had collected in the receiver. A very small amount of solid residue (from 0·5 to 1·25%) was left after evaporation of the sweat. Anselmino extracted the solid residue with alcohol of 833, evaporated the alcoholic solution to dryness, and then, by means of anhydrous alcohol, extracted from the saline residue an acid, extract-like matter, similar to the alcohol-extract of flesh, and containing free acetic acid, acetate of potash, and animal matter precipitable by tannic acid. Berzelius conceives the free acid of this extract (like the free acid in extract of flesh,) to be lactic acid. Now I will not assert that the sweat always contains free acetic acid, but I certainly have observed cases in which the odour clearly showed that the free acid was principally the acetic; lactic acid may, however, still be always present. The occurrence of acetic acid in

¹ Tiedemann's Zeitschrift, vol. 2, p. 321.

sweat is placed beyond a doubt by my experiments. The matters which are undissolved by anhydrous alcohol are principally chlorides of sodium and potassium, and spirit-extract; the latter is not precipitated by chlorine, protochloride of tin, or bichloride of mercury. In this investigation Anselmino seems to have overlooked, as Berzelius remarks, the hydrochlorate and lactate of ammonia. All that is insoluble in alcohol may be dissolved in lukewarm water, with the exception of a gray matter; this aqueous solution contains sulphates and an animal matter precipitable by tannic acid, and perchloride of tin, (water-extract.) The gray insoluble matter leaves on incineration a considerable amount of phosphate, together with a little carbonate of lime.

Anselmino has consequently arrived at results which entirely correspond with my own, excepting only that I could not in every case detect the presence of sulphates in fresh sweat, although I always found them in the incinerated residue; from this circumstance I am led to infer that some of the constituents of sweat contain sulphur.

In 100 parts of the solid residue of sweat Anselmino found:

Substances insoluble in water and alcohol, chiefly salts of lime	-	20
Water-extract and sulphates	-	210
Spirit extract, with chlorides of sodium and potassium	-	480
Alcohol-extract, acetic acid, and acetates (lactates)	-	290

These figures must be regarded merely as approximative. In 1000 parts of sweat there are contained, according to Anselmino:

Water	-	995.000	987.500
Epidermis and salts of lime	-	100	250
Water-extract and sulphates	-	1.050	2.625
Spirit-extract, chlorides of sodium and potassium	-	2.400	6.000
Alcohol extract, acetates, lactates, and free acetic acid	-	1.450	3.625

From 100 parts of dried residue of sweat Anselmino obtained 22.9 of fixed salts, consisting of carbonates, sulphates, and phosphates of soda and (in small quantity) of potash, chloride of sodium, phosphate and carbonate of lime, and traces of peroxide of iron.

The peculiar odour of sweat from different parts of the body is dependent in a great measure on the secretion of the sebaceous glands in those parts: thus it is well known that the sweat from the feet of many persons has a very penetrating odour, that the sweat from the axilla gives off a peculiar ammoniacal smell, and that the sweat of the external organs of generation contains and smells faintly of butyric acid.

The gases which are given off by the skin are, according to Collard de Martigny,¹ carbonic acid and nitrogen; they are not exhaled in constant, but in varying proportions, and generally in the greatest quantity after meals and after violent exertion. Collard has observed that an excess of carbonic acid is exhaled after the use of vegetable food, and an excess of nitrogen after a nitrogenous diet. Since these

¹ Magendie's Journal, vol. 10, p. 162.

gases are contained in a state of solution in the blood, (see p. 118,) it may readily be conceived that they will exhale at those points where the blood in its passage through the capillaries comes in the most intimate contact with the external atmosphere; at least it seems a simpler view to regard it as a mere physical process than as a disintegration of animal matter by the secreting organs. In fact, the cutaneous exhalation must be regarded, as Edwards has observed, in the light of a partly physical, partly organic process. The product of physical exhalation is pure water and gas; the product of organic exhalation contains animal constituents, which must be regarded as secretions of cells.

The amount of exhaled matter is liable to great variations: it is increased by a dry and light atmosphere; and is lessened by a moist, vapoury, dense, and calm atmosphere. During and immediately after meals the exhalation is at its minimum; it attains its maximum during the actual period of digestion. The cutaneous exhalation is in antagonism with the urinary secretion and the pulmonary exhalation, so that an excessive secretion of urine diminishes the action of the skin, and, conversely, the renal functions are less energetic when the skin exhales freely.

On Morbid Sweat.

Our knowledge of the chemistry of normal sweat is very imperfect; but our information respecting the changes which this secretion undergoes in disease is still more deficient. Our ignorance may be explained, and in some measure excused, by the extreme difficulty of obtaining, in a state of purity and unadulteration, a sufficient quantity of the secretion for the purpose of forming a successful chemical analysis.

Dr. Piutti, of Elgersburg, has had the kindness to present me with some sweat which he obtained from persons during the use of the water-cure, and also with a manuscript communication containing some analyses of sweat instituted by himself, which I shall at once proceed to enumerate.

The manner in which he conducted his analyses is not stated. We observe the absence of salts of lime in these analyses, and Piutti states that he could find no traces of phosphate or benzoate of lime, the former of which has indisputably been detected by other chemists. Since the phosphate of lime doubtless pertains to the epidermis, we may conclude that Piutti removed all the desquamated cuticle before he commenced his analyses.¹ All mention of sulphuric acid, and of potash, is likewise omitted. I have already stated that I only once detected traces of sulphuric acid in fresh sweat, although I always found a considerable quantity of it in the incinerated ash.

¹ Berzelius, however, is of opinion that a portion of phosphate of lime appertains to the sweat itself, and that it is held in solution by a free acid.

Piutti has made three analyses of the sweat collected from invalids. They gave the following results:

		1.	2.	3.
Water	-	995.5	993.0	994.6
Chloride of sodium	-	.30	.40	.33
Phosphate of ammonia	-	.5	.8	1.1
Acetate of ammonia	-	.5	.6	.5
Hydrosulphate of ammonia	trace			trace
Extractive matters	.5	1.6	.5	

The first analysis was made with the sweat of a man aged 36 years, who during twelve years had suffered from atonic gout, and had been trying the water-cure for ten weeks. The specific gravity of the sweat was 1003.5. The sweat in the second analysis was taken from a woman aged 54 years, who for six years had suffered from gout, and who had been under the water-cure for twelve weeks: its specific gravity was 1004. In the third case it was collected from a girl 22 years of age, suffering from paralysis of the lower extremities, but in other respects blooming and healthy. The animal matter in this case was of a greenish colour when isolated; it was soluble in ether, but not in alcohol. The specific gravity was 1003.

The sweat that was forwarded to me by Dr. Piutti, and which was enclosed in ounce-bottles with ground stoppers, was in a state of decomposition when I received it, and therefore was not in a proper condition for an accurate qualitative analysis. It smelt strongly of hydrosulphate of ammonia, especially a specimen collected from a man who had had psoriasis diffusa for seventeen years. The gray deposit which was found in every bottle consisted of desquamated epidermis. The sweat, to which I have just referred, had a penetrating odour of sulphuretted hydrogen, which continued during evaporation, and ultimately merged into a nauseous animal smell. Its specific gravity was comparatively high, being 1008; and it yielded 9.9 of solid constituents, which, after being exposed to the influence of a red heat, were found to consist of a large proportion of chloride of sodium, carbonate of soda, a little phosphate of lime, and a fair amount of sulphuric acid.

The statements which we possess from other sources, regarding the morbid changes of the sweat, are very loose and inconclusive; in fact, we have no accurate observations on the subject.

1. *The quantity of the sweat is sometimes increased in an extraordinary degree.*

Thus critical sweats are usually very abundant, continuous, and watery, in intermittent fevers, in rheumatic affections, and in colligative disorders.

2. *The quality of the sweat is changed.*

a. The sweat may be distinguished by a peculiar odour. The sweat of persons with the itch is said to have a mouldy odour, while that of syphilitic patients is said to smell sweet. The sweat of rheu-

matic and gouty persons has an acid smell, while in putrid fever and scurvy, it has a putrid odour; in jaundice it is said to resemble musk in its smell. In Stark's 'General Pathology,' (p. 1126,) we find it stated that the odour of the sweat in scrofula resembles that of sour beer, while in intermittent fever it smells like fresh-baked brown bread. The determination of odours is, however, very subjective, and (with a few exceptions) it is more than probable that different observers would detect different resemblances.

b. Some of the normal constituents may be abnormally increased.

1st. *The free acid of the sweat may be increased.* Lactic acid, which is the ordinary free acid, is usually increased in cases of rheumatism and gout; the sweat in these diseases has a strong acid reaction. When there is also an acid odour, acetic acid is present. Prout has found free acetic acid in the sweat of a person suffering from hectic fever. After an attack of acute rheumatism, the joints of the feet remained swelled, for which potash-baths were ordered. These baths, in the course of three weeks, brought on an attack of eczema, extending as high as the knee. The sweat from the feet had then a decided odour of acetic acid, which became more strongly developed when they were sharply rubbed. Anselmino¹ found free acetic acid in the sweat of women during their confinement; and, according to Stark, the quantity of free lactic acid is increased in the sweat during scrofula, rachitis, and certain cutaneous eruptions.

2d. *The ammonia of the sweat may be increased.* Anselmino found a larger proportion of (free?) ammonia in the sweat after an attack of gout than in any other case. Berend² states that the sweat in putrid and typhus fever is ammoniacal; and in nervous diseases(?), according to Nauche,³ it becomes alkaline. All sweat with a putrid odour probably contains free ammonia.

3d. *The salts may be increased.* Prout⁴ observed that in the case of a man with dropsy the skin became covered with a white saline crust of chloride of sodium, after an abundant perspiration. Anselmino found in the sweat, after a severe attack of gout, more salts than usual. In cases of gouty and urinary concretions, the quantity of phosphate of lime appears to be increased.

c. Abnormal constituents may be present in the sweat.

1st. *Albumen* has been observed by Anselmino in a critical sweat, which broke out in large quantity one evening over the whole body in a case of febris rheumatica, with severe pains in the joints; on the following day it had disappeared. Stark asserts that albumen may be found in the sweat in gastric, putrid, and hectic diseases, and also on the approach of death, in consequence of the abnormal solution of the solid constituents. I failed in detecting any certain indications of albumen in sweat collected (by means of linen washed with dis-

¹ Tiedemann's Zeitschrift, vol. 2, p. 223.
² Vorlesungen über Semiotik, p. 388.

³ Stark, p. 1127.
⁴ London Med. Gaz. vol. 15, Oct. 1834.

tilled water) from the breast of a person in the colliquative stage of tubercular phthisis.

3d. *Blood or its constituents.* Voigtel¹ observed an instance of bloody sweat from under the arm of a young man; it appeared after any violent exertion. In scurvy, putrid fever, and typhus icterodes, bloody sweat has likewise been observed.

3d. *Uric acid* is stated to have been found in the sweat of arthritic persons (Stark.) Wolff² found that the sweat which had hardened on the forehead into a solid white substance, (in a patient with stone in the bladder,) contained uric acid. Urate of soda is likewise stated to have been found in the sweat of persons suffering from gout or stone.

4th. *Bilin and biliphæin* have been found in the sweat of persons with jaundice, and sometimes in such large quantity as to colour the linen yellow, and to communicate a bitter taste to the perspiration. According to Berend, the sweat in febris putrida biliosa likewise contains bile-pigment.

5th. *Red colouring matter of the urine (uroerythrin)* was found by Landerer³ in sweat from the axilla of a fever patient. A blue colouring matter, doubtless allied to cyanurin, has occasionally been observed in the sweat. Dr. Bleifuss⁴ has seen blue sweat from the foot of a patient with disease of the abdomen. Michel has likewise observed it in an hysterical woman and in a hypochondriacal man; it was most marked on the right side of the body. Billard⁵ observed a blue sweat on the upper part of the body of a girl.

6th. *Fat* is stated to occur in colliquative hectic sweats.

d. Substances altogether foreign to the animal organism may be conveyed, through the process of digestion, into the blood, and thus occur in the sweat.

Landerer⁶ has observed in his own person that after taking large doses of quinine, the sweat assumed a bitter taste of the drug. The following substances enter into, and have been detected in the sweat: sulphur, mercury, iodine, iodide of potassium, asafoetida, garlic, saffron, olive oil, rhubarb, indigo, prussian blue, and copper. (Stark, General Pathology, p. 1127; Baumgärtner, Elements of Physiology and Therapeutics, p. 486.)

Many of these statements, regarding the change undergone by the sweat in disease, are fully confirmed; some must, however, still be regarded as doubtful.

Sweat of animals.

Anselmino has analyzed the sweat of the horse, the only animal of whose sweat we have any accurate knowledge. He used for his ana-

¹ Stark, p. 1131.

² Diss. sing. casum calculositatis. Tab. 1817.

³ Buchner's Report. 2d series, vol. 5, p. 234.

⁴ Württemberg, Med. Correspond. Blatt. 1835, No. 26.

⁵ Forstep's Notiz. 32.

⁶ Buchner's Report. 16, p. 233.

lysis the scaly matter that falls from horses during the process of currying, in the form of a white powder, and consisting of dried sweat mixed with a considerable amount of dirt and epithelium. It contained, 1st, a substance with an acid reaction, soluble in anhydrous alcohol, alcohol-extract, together with an alkaline lactate or acetate; 2d, an extract-like matter, soluble in alcohol of '833, and possessing an odour like that of the horse, together with chloride of sodium; 3d, an extractive matter soluble in, and communicating a brown colour to water, and precipitable by infusion of galls, together with chloride of sodium and sulphates. The portion still undissolved evidently consisted of epithelium. Anselmino regarded it as coagulated albumen; doubtless it was in it that the phosphate of lime and magnesia occurred, which were recognised in the ash of the sweat. The ash consisted of sulphates of potash and soda, chlorides of sodium and potassium, a large proportion of the phosphates of lime and magnesia with traces of iron, but no alkaline carbonates or phosphates. Anselmino seems to have overlooked the ammonia-salts, for it is only by the presence of hydrochlorate of ammonia that we can explain how it is that the ash contains no alkaline carbonate, while the alcohol-extract contains either lactate or acetate of potash. The presence of acetic acid was established by a separate experiment. Fourcroy and Vauquelin sometimes found small quantities of urea in horses' sweat, but Anselmino could never detect it.

Fat.

The minute sebaceous glands (*folliculi sebacei*) which are distributed over the whole surface of the body, secrete a peculiar fat, which renders the skin supple and flexible, and hinders it from being permeated by water. The composition of this fat varies in different parts of the body, as is clear from the variety of smell which it evolves in the axilla, on the generative organs, on the scalp, and on the feet of many persons. It is usually of a pale yellow colour, not viscid, and insoluble in water, with which, when it is rubbed, it forms an emulsion. It contains relatively only a small amount of true fat, and is associated with several other animal matters, (as, for instance, albumen, and extractive matter,) and a considerable amount of inorganic salts. Esenbeck has made an analysis of the fat collected in an enlarged sebaceous gland. It did not coagulate on boiling, and was precipitated by acids, corrosive sublimate, and tannin. It contained in 100 parts:

Stearin	-	-	-	-	24·2
Extractive matter, with some olein	-	-	-	-	12·6
Salivary matter	-	-	-	-	1·6
Albumen with casein (?)	-	-	-	-	24·2
Phosphate of lime	-	-	-	-	20·0
Carbonate of lime	-	-	-	-	2·1
Carbonate of magnesia	-	-	-	-	1·6
Traces of acetate of soda, chloride of sodium, and loss	-	-	-	-	3·7

CHAPTER VII.

THE URINE.

THE urine is an extremely complex fluid, but the relative proportions of its different constituents are not very variable. The following are the ordinary constituents of healthy human urine: urea; uric acid; [hippuric acid;] extractive matters, embracing alcohol-extract, spirit-extract, and water-extract, with their respective constituents; mucus; brown colouring matter of the urine (*hæmaphæin*); red colouring matter of the urine (*uroerythrin*); carbonic, lactic, hydrochloric, sulphuric, phosphoric, silicic, and hydrofluoric acids;¹ soda; potash; ammonia; lime; magnesia; and peroxide of iron.

Recently discharged urine ordinarily possesses the mean temperature of the body; it is of an amber yellow colour, perfectly transparent, has a well-marked acid reaction, and exhales a peculiar but not disagreeable odour, which it loses on cooling. Its specific gravity fluctuates from 1005 to 1030, the average being about 1012.5. It has a saline and disagreeably bitter taste; it undergoes no apparent change upon being heated to the boiling point, and its behaviour towards reagents is dependent upon that of its various constituents, although modified by the very dilute state in which they occur. Acids, with the exception of the oxalic, which produces a turbidity, throw down no precipitates; the free alkalies, on the contrary, throw down the phosphate of lime: the salts of baryta, silver, and lead, cause precipitates; so also does tannin, but in a less degree.

When urine is left to itself for some time, slight nebulæ, consisting of mucus, are formed in it, which gradually descend to the bottom. Soon after the appearance of this phenomenon, an unpleasant odour is developed; instead of an acid, an alkaline reaction is observed, and carbonate of ammonia is formed, which causes more or less turbidity, by precipitating the ammoniacal-magnesian phosphate, and phosphate of lime. A portion of these salts, associated with mucus, forms a greasy whitish scum, in which, by means of the microscope, beautiful crystals of ammoniacal-magnesian phosphate may be seen, mixed with an amorphous mass of phosphate of lime and decomposed mucus. On treating the urine in this state with hydrochloric acid, it effervesces, in consequence of the presence of carbonate of ammonia. If the urine is allowed to stand for a still longer period, the smell becomes more disagreeable; cubic, and four- and six-sided prismatic crystals, composed of chloride of sodium, hydrochlorate of ammonia, and phosphate of soda and ammonia, are produced in consequence of the concentration produced by the spontaneous evaporation, and the urine ultimately becomes covered with a sort of mould, which is usually of a blue or bluish-gray colour.

¹ [In addition to these constituents, two new acids, to which no names have been yet assigned, have been described by Pettinkofer and Heintz.]

We have no certain knowledge regarding the manner in which the acids and bases combine to form salts in fresh healthy urine. We may fairly conclude that the chloride of sodium pre-exists in it; the sulphuric acid is generally supposed to be united with potash, phosphoric acid with lime and magnesia, and if (as is generally the case) more phosphoric acid be present than is required for the saturation of these earths, the excess combines with soda, and if there be not sufficient soda present to effect the saturation of the acid, the ammonia combines with it, forming the biphosphate of ammonia. The lactic acid of the urine is partly free, and partly combined with ammonia, potash, and soda. Hydrochlorate of ammonia is also supposed to pre-exist in the urine. Carbonic acid, when it occurs in the urine, is held in solution and in a free state. Uric¹ acid is supposed by Berzelius to exist in a free state in solution in the urine, although warm urine usually holds a larger quantity of uric acid in solution than an equal quantity of water at the same temperature could retain. There is, however, this point in favour of his view, that the uric acid, which separates spontaneously from the urine on cooling, contains mere traces of ammonia and soda, and he conceives that, in all probability, the uric acid is held in solution through the agency of some of the other constituents of the urine.

[Liebig² has shown that uric acid possesses the property of combining with a portion of the soda of the alkaline phosphate of soda, and acquires in the combination a higher degree of solubility than it possesses in its uncombined state, at the ordinary temperature of the body. By this reaction there are produced a urate of soda and an acid phosphate of soda.]

Prout, on the contrary, is of opinion that the uric acid is held in solution in the urine in the state of urate of ammonia, a combination which probably always occurs in healthy urine, and which is often found in large quantity in the urine of diseased persons, giving rise to the formation of sediments. The real state of the case may be, that normal urine contains both free uric acid and urate of ammonia.

Qualitative analysis of healthy urine.

The qualitative analysis of healthy urine seldom presents any great difficulty. Many of its constituents may be detected with ease, unless, as is sometimes the case, they exist in very minute quantity. Others, as for instance the extractive matters, can only be detected with any degree of certainty by isolating them, in the same manner as is done in quantitative analysis.

The analysis of the urine is something like that of mineral waters;

¹ [It is stated in page 54, that the formula for hydrated uric acid is $C_{10}N_4H_6O_8 + HO$. From various analyses of urates by Bensch (Liebig's Annalen, vol. 54, p. 189,) there is reason to believe that the true formula is $C_5N_4HO_8 + HO$.]

² Lancet, June, 1844.

some of the constituents may be at once recognised by the addition of a test, while we can only be assured of the presence of others, by separating them in a distinct and isolated state.

The specific gravity of the urine is most accurately determined by the ordinary 1000-grain glass bottle. An areometer will give the result with less trouble, but, at the same time, with less accuracy.

Becquerel¹ has published a table for the purpose of enabling us to calculate the amount of the solid constituents in a known weight of urine, from the observed specific gravity, [but it has been proved to give results on which no dependence can be placed.²]

1. *Urea.* This constituent seldom occurs so abundantly in the urine, as to be immediately detectible by the addition of any reagent. A portion of urine is usually evaporated in the water-bath to the consistence of a syrup, anhydrous alcohol is added, and the alcoholic solution is filtered, and evaporated on the water-bath nearly to dryness; some drops of water, and subsequently of nitric acid are added, upon which crystals of stellar and foliated shapes very speedily develop themselves.

Upon leaving the alcoholic extract to spontaneous evaporation, long acicular crystals of urea will be formed; on examining some of them under the microscope, they will be found to present the appearance of four-sided prisms, as shown in figure 20. If, (which however is not often the case,) the urea should be present in very small quantity, and no crystals are formed for some time after the addition of nitric acid, it only requires a microscopic examination to ascertain whether the crystals are those of nitrate of urea: if they are, they will occur in the forms indicated in fig. 21. If, instead of nitric, oxalic acid has been used for the detection of the urea, we obtain the forms represented in fig. 22.

2. *Uric acid.* It is but seldom that the uric acid exists in such large amount, as to be precipitated in the form of a fine crystalline red sediment when the urine cools. When, however, this is the case, the crystals, under the microscope, exhibit the rhomboid form shown in fig. 23. Another method of proving that the sediment consists of uric acid, is to place some of it in a porcelain capsule moistened with nitric acid, and to apply heat till the acid evaporates. A purple-red colour then appears which is characteristic of uric acid: this colour becomes more intense on the approximation of a rod dipped in ammonia. If no crystalline sediment is deposited as the urine cools, two or three drachms of hydrochloric acid must be added to six or eight ounces of urine, and the mixture must be allowed to stand, covered, for twenty-four to forty-eight hours. A red or reddish-brown sediment of uric acid then separates, consisting of crystals of the forms represented in fig. 23a, and 23b.

¹ Sémiotique des Urines, p. 17.

² [On the specific gravity of the urine in health and disease, especially in diabetes and granular degeneration of the kidneys. By George E. Day. Lancet, June 15, 1844.]

2*. [Hippuric acid is regarded by Liebig¹ as an invariable constituent of ordinary human urine. "All the urine taken in this country from individuals living upon a mixed animal and vegetable diet, contains hippuric as well as uric acid, and about the same proportion of both acids. Hippuric acid may be obtained in the following manner, even from proportionally small amounts of fresh urine:—Fresh urine is evaporated in a water-bath to the consistence of a syrup; it is then mixed with some hydrochloric acid, and agitated with its own volume of ether, which latter substance dissolves the hippuric acid. It usually happens that the mixture does not separate spontaneously, but that the ether remains enclosed by the fluid, like froth; the separation of the ether takes place immediately upon adding to the mixture, after having allowed it to stand at rest for an hour, one-twentieth part of its volume of alcohol. In this case the froth disappears, and the fluid separates into two layers; the upper layer contains the hippuric acid in solution; but besides it also contains urea, owing to the addition of the alcohol. This upper layer is carefully removed by means of a pipette or siphon, and agitated with small portions of water; the water removes the alcohol and the urea, whilst the hippuric acid remains in solution in the ether. By evaporating the ethereal solution the hippuric acid is obtained in crystals. The crystals produced are usually of a yellowish or brown colour, arising from the presence of a resinous substance, which may be easily and completely removed by means of charred blood.²

"In its pure state the hippuric acid produced from human urine presents the same long, shining, transparent, four-sided obliquely-truncated prisms, by which the hippuric acid produced from the urine of animals is so easily detected and distinguished from benzoic acid. (See fig. 23.) The hippuric acid of human urine is not volatile at the subliming temperature of benzoic acid; at a higher temperature it undergoes fusion, forming a brown-red liquid, and yielding upon dry distillation the same products which common hippuric acid forms under the same circumstances, viz., a red-coloured oil smelling like tonka-beans, ammonia, benzoic acid, and a copious residue of carbon. It dissolves in nitric acid at a high temperature, and yields, upon cooling, crystals of benzoic acid, owing to the decomposition which it undergoes.

"From 0·499 of hippuric acid produced from urine, 1·0791 of carbonic acid and 0·2317 of water were obtained. This gives for 100 parts—

¹ Lancet, June, 1844.

² [The following is a simple method of obtaining pure crystals of hippuric acid from human urine. Evaporate the urine till there is a copious deposition of salts. Add strong alcohol, and place the mixture in a stoppered bottle. With the aid of a gentle heat, (for instance, by placing the bottle in warm water,) we ensure the solution of the urea, the lactates (if any are present) and the hippurates in the alcohol, whilst the urates remain with the insoluble constituents. When the supernatant fluid is perfectly clear, it must be decanted, evaporated very nearly to dryness, and redissolved in hot water. If a stream of chlorine be passed through the aqueous solution, the urea is destroyed; and by gradual concentration, and the addition of a little free mineral acid, we obtain crystals of hippuric acid.]

	Found.	Calculated.
Carbon	59·47	60·89
Hydrogen	5·15	4·45

This analysis corresponds sufficiently with the calculated results to remove all doubt as to the nature of the acid; it will be perceived that it contains $10\frac{2}{3}$ less carbon than benzoic acid.”]

3. *Extractive matters.* The exhibition of the divisions of extractive matter, namely, the water-extract, the spirit-extract, and the alcohol-extract, can only be effected by evaporating the urine, and treating it with alcohol, as we shall presently show in speaking of the quantitative analysis of this fluid. Little has yet been done in this department of chemistry, but the presence of the extractive matters can generally be easily recognised by the addition of certain tests: for instance, acetate of copper, chloride of tin, perchloride of iron, and sulphate of protoxide of iron, throw down precipitates from freshly-passed urine; and bichloride of mercury, nitrate of tin, and tannic acid, cause a degree of turbidity. There is, however, no certain proof, although there is every probability that normal urine in all cases behaves in this way with the above tests. The extractive matters which I formerly separated from the urine were not precipitated by the salts of iron, while, on the contrary, its perchloride throws down a copious precipitate in a specimen of urine, which I am now analyzing.

Berzelius states, that after urine has been neutralized by an alkali, precipitates are induced by the salts of zinc, tin, and mercury: I find that fresh urine, with a strong acid reaction, becomes clouded or deposits a sediment upon the addition of these salts.

4. *Mucus.* Mucus in the urine is readily detected by the microscope. We take up with a spoon a portion of the separated nebulous matter, and on placing it on the object-glass we can easily recognise the mucus-granules, and frequently a few epithelium-scales.

5. *Hæmaphæin.* It is this constituent which gives to healthy urine its amber or brownish-yellow colour. The variations in the tints of the urine are dependent upon the quantity of this colouring matter.

[Scharling¹ has recently examined the brown organic matter which gives the colour to inspissated urine, and seems also to be the source of its peculiar odour. By treating urine concentrated by the application of a freezing mixture, with ether, and evaporating, he obtained a brown fusible resinous mass, which he calls *oxide of omichmyle*, and supposes to contain a radical, *omichmyle*, the composition of which is still unknown.

It has a strong odour of castoreum, and when heated smells like

¹ Ann. der Chemie und Pharmacie, vol. 42, p. 265.

urine. It dissolves in alcohol, forming a solution that reddens litmus. It burns with a clear flame, leaving scarcely any ash.]

6. *Uroerythrin.* This red colouring matter exists only in very small quantity in healthy urine, and cannot be easily detected by tests. It is always associated with uric acid, and seems to increase and decrease in the same proportion as that constituent. It is precipitated with the uric acid and ureate of ammonia, to the former of which it appears to enact the part of a mild base, imparting to it a more or less deep red colour. This constituent can therefore be detected by the addition of hydrochloric acid to the urine, in the manner already described in speaking of uric acid. In some few diseased states, we find a gray or yellow precipitate of uric acid, as if this constituent was present in large quantity, while the uroerythrin was deficient: on the addition, however, of hydrochloric acid, dark coloured uric acid is soon precipitated.

7. *Carbonic acid* is probably a constituent of healthy urine, existing in a state of solution: in order to detect it, fresh urine must be warmed in a retort, the neck of which rests a few lines under the surface of lime-water. The presence of carbonic acid renders the lime-water turbid. In order to guard against the production of carbonate of ammonia, we must take care that the urine is not submitted to too powerful a heat, and that the distillation is not carried too far.

[The following method is far less liable to give erroneous results.. It is founded on the principle that one gas passed through a solution of another will displace it, so that hydrogen or nitrogen will liberate carbonic acid and dissolve in its place. A series of Wolfe's bottles must be arranged, so that hydrogen gas evolved in the ordinary manner from the first shall pass through a strong solution of caustic potash to free it from any carbonic acid that may be mixed with it, and then through another bottle containing lime-water, in order to certify its purity ; in the next bottle through the urine to displace the gas dissolved in it, and, finally, through lime-water a second time, to show if the displaced gas were carbonic acid or contained it:]

8. *Lactic acid* is always present in the urine, imparting to it an acid reaction. It may be presumed that the carbonates which are left upon the incineration of the solid residue of the urine correspond to the lactates, because lactates with fixed bases are transformed into carbonates by incineration, and because the other salts which occur in the urine, the sulphates, phosphates, and hydrochlorates, are not similarly changed. It may, however, happen that no carbonic acid is found in the ash, although there has been a large proportion of lactic acid in the urine; for if the urine contained only free lactic acid, or lactate of ammonia, or even the lactates of soda and potash, at the same time with phosphate of ammonia or chloride of ammo-

nium, the ash might be devoid of carbonic acid, in consequence of the liberated phosphoric or hydrochloric acid uniting with the base.¹

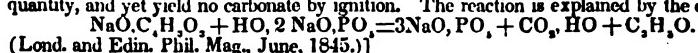
In this case the lactic acid would have to be determined analytically. The alcohol-extract of the urine contains both free lactic acid and alkaline lactates; after dissolving it in absolute alcohol, precipitating the bases by sulphuric acid, filtering, evaporating the alcohol, dissolving the residue in water, and digesting the acid solution with oxide of zinc, we obtain a lactate of zinc, which may be decomposed by free baryta. This is certainly a very tedious proceeding for the mere qualitative determination of lactic acid, and need never be adopted: since, as far as I am aware, the ash (more especially the ash of the spirit-extract,) always contains carbonates, and as the presence of lactic acid in healthy urine has been sufficiently proved by Berzelius.

[It is well known that Liebig denies the existence of lactic acid and the lactates in the urine; and as the subject has recently attracted much attention, I have thought it advisable to state the grounds upon which that chemist has arrived at his conclusions. "Lactic acid," he observes, "is a non-nitrogenous substance. Nothing has hitherto been observed tending to show that it may be produced from the elements of a nitrogenous substance, by the decomposition of such a substance and the transposition of its elements. In every instance where the formation of lactic acid has been observed, the result of careful examination has proved the presence of a non-nitrogenous substance of an identical, or, at least, similar composition with that acid.

"These observations would seem to render the formation of lactic acid in the body of the herbivorous and graminivorous animals, which take starch and sugar in their food (substances from which lactic acid may be formed,) not merely possible, but in many cases highly probable; and yet, strange to say, chemists have hitherto attempted in vain to detect lactic acid in the urine of the cow and of the horse. The urine of the cow or horse has no acid reaction; on the contrary, its reaction is strongly alkaline: it contains carbonated, hippurated, or benzöated alkali, or alkalies combined with mineral acids, but no trace of any *lactate*.

"In contrast with this, the urine of man, and of carnivorous animals, manifests, when in a healthy state, a strongly acid reaction. Now, it is precisely in analyses of the blood and urine of man, and of carnivorous animals, that we find lactates mentioned as solid constituents; not because they have in reality been detected in these fluids—for no one has as yet succeeded in producing lactic acid therefrom—but because, upon examining the aqueous and alcoholic extracts

¹ [It has been recently shown by Dr. Golding Bird that an alkaline acetate (and the observation applies equally to a lactate) may exist in a solution of phosphate of soda in considerable quantity, and yet yield no carbonate by ignition. The reaction is explained by the equation:



of blood and urine, some non-crystalline matters have been found which sometimes manifested an acid reaction, and upon incineration left a carbonated alkali as a residue, thus presenting a remote similarity in deportment to the alkaline lactates.

"From what substance could lactic acid be formed in the body of carnivorous animals? With the exception of fat, they partake of no non-nitrogenous matter in food, no substance, in fact, so far as we know, capable of producing lactic acid. Carnivorous animals partake of no sugar, no starch, no gum, no mucus; there is a total absence of the non-nitrogenous substances which form so large a part of the aliments of herbivorous and graminivorous animals.

"The assumption, *a priori*, that neither the blood nor any other fluid in the body of carnivorous animals can possibly contain any lactic acid, has been positively established by the experiments of Enderlin, (*Annalen der Chemie und Pharmacie*, vols. 49 and 50.) Finally, Pelouze has proved that the experiments of Henry, who pretended he had detected lactate of urea in urine, are erroneous, and by no means to be relied upon.

"Consequently, as our knowledge of this subject stands at present, the acid reaction of urine cannot proceed from lactic acid. And although processes of transposition take place in the healthy animal body, rendering insoluble substances soluble in the stomach and bowels, yet these processes are of a different kind from that process of putrefaction of casein in milk which causes the formation of lactic acid.

"Direct experiments prove that fresh urine, of a strongly acid reaction, and taken from various healthy individuals, when cautiously neutralized with baryta water, does not retain in solution the least detectable trace of baryta. Now, as lactate of baryta is readily soluble in water, the urine would certainly, and of necessity, contain baryta, if its acid reaction were really owing to the presence of lactic acid. Upon the addition of the very first drop of the baryta water to urine an extremely copious precipitate is formed; this precipitate contains urate and phosphate of baryta and of lime, but no detectable trace of baryta is found, even although only just so much baryta water is added as to leave the urine still possessing a feebly acid reaction.

"Carbonate of magnesia and calcined magnesia act upon urine in precisely the same manner. If either of these substances be mixed with water, so as to form a milky fluid, and be then added to urine with an acid reaction, the acid reaction will immediately cease, and a very considerable white precipitate be formed. The fluid now manifests a feebly alkaline reaction, and contains a trace of magnesia in solution. It is a remarkable circumstance that magnesia withdraws the phosphoric acid from the urine so completely, that a mixture of perchloride of iron and acetate of potash no longer indicates a trace of phosphoric acid in the urine which has thus been treated with magnesia.

"Had lactic acid been the solvent of the lime and magnesia present in the urine, one would have expected that a corresponding amount of baryta, or of magnesia, would have taken its place upon its separation. But, as I have already observed, not a trace of baryta is found in solution when that substance has been employed for neutralizing the acid, and only a slight trace of magnesia when it has been used for the same purpose.

"But as urine contains a certain amount of alkaline phosphates, i. e. phosphate of soda and phosphate of potash, and as baryta and magnesia form, with phosphoric acid, insoluble salts, it might have been supposed that the neutral lactates formed upon the neutralization of the urine with the two bases, had been decomposed, together with the phosphates of soda and potash contained in the urine, and transposed themselves anew, with these substances, into phosphate of baryta or of magnesia, and into neutral lactate of potash or soda. In this case neither baryta nor magnesia could remain in solution. This circumstance, therefore, renders these experiments indecisive, and leaves the question as to the presence or absence of lactic acid in urine dependent upon more direct experiments.

"I employed putrid urine in my attempts to detect lactic acid, because lactic acid is not destroyed by putrefaction, and it must, therefore, of necessity be present in putrid urine if it really forms a constituent of fresh urine; and because if lactic acid can at all be formed by the putrefaction of urine, from matters containing previously no lactic acid, the question whether lactic acid is to be reckoned among the constituents of normal urine is at once practically decided; or, more correctly speaking, the problem is proved to be impossible of solution, since we possess no means of positively determining which urine may be considered of a normal constitution, and, on the contrary, which is, to this extent, abnormal.

"As matters at present stand, therefore, with regard to this subject, it was immaterial whether the presence of lactic acid was detected in fresh or in putrid urine; if it was found to exist in the latter, this fact must be considered as a confirmation of Berzelius' examination of fresh urine; whilst its absence from putrid urine would justify us positively in asserting that it does not form a constituent of fresh urine; and, moreover, that urine contains no substance giving origin, by means of putrefaction, to the formation of lactic acid.

"I have come to the latter conclusion. I have found it impossible to detect the presence of lactic acid in putrid urine; and if we examine somewhat more closely and minutely the experiments made by Berzelius, and from which he inferred the presence of lactic acid in urine, we find that not one of them amounts to a positive proof that lactic acid really forms a constituent of fresh urine.

"The experiments which I made for the purpose of ascertaining the presence of lactic acid in putrid urine are the following:

Putrid urine was first evaporated over an open fire, and afterwards to dryness in a water-bath; the residue was treated with a mixture of

alcohol and sulphuric acid, which caused the solution of phosphoric acid, hydrochloric acid, and of lactic acid also, if this latter substance were really present. The fluid obtained was saturated with oxide of lead, and then filtered off from the phosphate, sulphate, and chloride of lead formed; the lead contained in solution in the filtrate was separated by means of sulphuretted hydrogen. The solution thus freed from lead, and which ought to have contained the lactic acid had there been any present, was evaporated in a water-bath, and the residue treated with alcohol: a quantity of common salt remained. In order to remove the soda from the alcoholic solution, effloresced oxalic acid was dissolved in the latter, at a high temperature, and the oxalate of soda formed, was separated from the fluid by filtration; the fluid was then saturated with oxide of lead, which again gave rise to the formation and separation of chloride of lead. The solution was, by means of sulphuretted hydrogen, again freed from the lead which had dissolved, then concentrated in the water-bath, and basic acetate of lead added in excess; a copious white precipitate was formed, from which the fluid was filtered off. This fluid must contain the lactic acid if any had been present in the urine; the lead which this fluid held in solution was precipitated by means of sulphuretted hydrogen, the fluid filtered off from the precipitate, concentrated in the water-bath, and boiled with hydrate of baryta: a quantity of ammonia was expelled by this operation. After the decomposition of the ammoniacal salt the new-formed salt of baryta was cautiously decomposed, by means of sulphate of zinc, and every possible means was applied to obtain from this fluid, crystals of lactate of zinc, but without success; no trace could be discovered.

"The white precipitate obtained by means of the basic acetate of lead contained hydrochloric acid, and a brown resinous substance, which, upon combustion, comported itself like an animal substance.

"In other experiments the putrid urine was boiled until all the carbonate of ammonia it contained was completely expelled; then, with addition of hydrate of lime to destroy the remaining salts of ammonia, evaporated to dryness, and the residue treated with cold water, which must have dissolved lactate of lime had any lactic acid been present in the urine. The aqueous extract was evaporated to dryness, and the residue again treated with alcohol; the fluid obtained contained a copious amount of lime combined with an organic acid; the lime was then removed by the addition of oxalic acid, and the excess of oxalic acid by the addition of oxide of lead; the minute trace of dissolved oxide of lead was removed by means of charred blood.* The fluid obtained was very acid; it contained hydrochloric acid, which was removed by the addition of oxide of silver; a portion of the fluid filtered off from the hydrochlorate of silver was saturated with oxide of zinc, and left to crystallize, but no lactate of zinc was obtained; the fluid settled into a dark-coloured resinous mass. Another portion of this acid fluid was evaporated in the water-bath; a quantity of acetic acid was expelled during the evapo-

ration, and there remained at last only a very minute amount of a resinous matter, which upon calcination emitted a very fetid odour.

"All the other experiments, which I made in order to detect lactic acid in putrid urine, and a detailed description of which would be as tedious as useless, gave the same negative result. These experiments were usually made upon quantities of from forty to fifty pounds of urine, so that even a very minute amount of lactic acid, if really present in the urine, could not have escaped detection. All these experiments indicated the presence of an organic acid, but after the removal of all the inorganic acids and bases contained in the urine, this acid turned out to be a mixture of acetic acid with a brown resinous substance rich in nitrogen.

"The presence of acetic acid in putrid urine does not warrant us to infer that this acid is present also in fresh urine; on the contrary, the experiments made with regard to this matter prove that fresh urine contains no acetic acid. I have treated it exactly in the same manner as putrid urine, and have, by distillation with oxalic acid, obtained a fluid of a strongly resinous odour, but not possessing any acid reaction. When employing sulphuric acid and hydrochloric acid the distillate was acid, but the acid reaction proceeded from hydrochloric acid."

In the analyses of Lehmann, to which we shall presently refer, the lactic acid is determined quantitatively in a large number of cases. The following independent investigations of Heintz and Pettinkofer are important, as offering a clue to the real nature of the crystals assumed by Lehmann and other chemists, to consist of lactate of zinc.

In the observations of Liebig, quoted above, it is assumed that as lactic acid is not destroyed by putrefaction, it cannot be altered in putrescible urine. Heintz conceived that during the putrefaction of the urine certain causes might prevail to cause the destruction of the lactic acid, and in order to determine the point he instituted the following experiment.

"About fifty pounds of fresh urine, obtained from several young healthy men, were first evaporated over a free fire, and then in the water-bath; the extract obtained, exhausted with alcohol, to which a sufficient quantity of dilute sulphuric acid had been added. The acid solution was saturated with oxide of lead, the precipitate filtered, the liquid much evaporated, and the urea contained in this concentrated solution precipitated with pure oxalic acid. A considerable quantity of oxalate of urea was obtained, which, after washing with water and re-crystallization, separated in perfectly white, large crystals. The liquid, separated by pressure from the urea, from which it was now almost free, was evaporated to dryness, extracted with alcohol, and effloresced oxalic acid added to the solution to remove the soda. The oxalate of soda was separated by filtration, the filtered solution saturated with oxide of lead, and then precipitated with basic acetate of lead. The lead was removed from the filtered

liquid by sulphuretted hydrogen; the filtered solution was concentrated over the water-bath, and boiled with hydrate of baryta, when a considerable disengagement of ammonia resulted. The salt of baryta obtained in solution was decomposed with sulphate of zinc, in such a manner that only a slight excess of this latter remained in the solution. It was then evaporated to a small volume, when some delicate microscopic crystals separated, which were at first taken for lactate of zinc, but on examination under the microscope they soon proved to be distinct. The lactate of zinc, for instance, forms needles with acute dihedral summits, while the crystals of the zinc salt obtained from the urine have truncated terminal surfaces. To ascertain more precisely the nature of the acid combined with the oxide of zinc in this salt, the crystals were separated as carefully as possible from the mother-ley, pressed between blotting-paper, dissolved in a large quantity of boiling water, in which they were but sparingly soluble, and allowed to crystallize by cooling. The mother-ley afforded more crystals on further evaporation. They were again separated from adhering liquid by pressure.

"The zinc salt thus obtained had a faint greenish-yellow tint, and was therefore probably not quite pure, although its solution was perfectly colourless. The acid was isolated from this salt by means of sulphuretted hydrogen; after separation of the sulphuret the solution was entirely free from zinc. The liquid, which had a strong acid reaction, was freed by boiling from the excess of sulphuretted hydrogen, and evaporated on the water-bath. When it had become sufficiently concentrated, the acid separated in prismatic crystals, which appeared to form quadrilateral rectangular columns and tables. It is easily soluble in water, and separates in crystals on evaporation; the solution has a strong acid taste, and reddens litmus-paper. It likewise dissolves in alcohol, but not quite so easily as in water; ether dissolves scarcely a trace of it. Heated on platinum foil it melts, becomes brown, and leaves behind a coal, which is difficult of combustion, but which disappears entirely by stronger heat.

"From the mode of preparation it is evident that the acid forms with oxide of zinc a very sparingly-soluble salt, which separates in microscopic crystals. When the acid is supersaturated with ammonia, and the solution evaporated on the water-bath, so much ammonia escapes that it again becomes acid; if it be evaporated to dryness, so that all the ammonia that could escape at this temperature is expelled, and caustic potash be added to the mass, a considerable quantity of ammonia is given off; therefore it appears that this acid, like many organic acids, forms acid salts. The ammonia-salt obtained in this manner is somewhat more difficult of solution in water than the acid itself. When the acid is accurately neutralized with potash, it forms an easily-soluble salt, the solution of which affords no precipitate with sulphate of copper. The oxide of copper is not thrown down from this mixture by an excess of potash, but the

colour of the solution becomes somewhat darker. Acetate of lead produces a slight turbidity, most probably arising from a small quantity of some impurity. No precipitate is obtained with nitrate of silver, and the mixture, after having been rendered ammoniacal, is not altered by boiling. A solution of perchloride of iron, rendered neutral by ammonia, produces no precipitate. It differs, therefore, in this respect from hippuric acid.

"The author has not yet been able to ascertain the composition of this acid, in consequence of the small amount which he obtained from 50 lbs. of urine. It amounted to about eight grains, and was not perfectly white. But it was easy to prove that it contained nitrogen in considerable quantity."¹

Pettenkofer precipitates the alcoholic extract obtained from carefully evaporated human urine, previously neutralized with carbonate of soda, with a concentrated alcoholic solution of chloride of zinc. A brown amorphous precipitate containing zinc is soon thrown down; but after standing for several hours, small granular and rather hard crystals are deposited on the sides of the glass, which gradually increase to such an extent as to form perfect incrustations. On collecting the amorphous precipitate and the crystals on a filter, and boiling with a sufficient quantity of water, the amorphous precipitate remains insoluble, while the crystals gradually dissolve. On evaporating the aqueous solution a yellow crystalline residue is obtained, which in many of its physical characters resembles lactate of zinc. Under the microscope these crystals appear as very beautiful four-sided prisms, with an oblique terminal surface. They are with difficulty soluble in water, and are insoluble in strong alcohol and ether. In the aqueous solution we may detect chlorine, zinc, and an organic substance very rich in nitrogen. Repeated boiling with strong alcohol, or washing with cold water, removes all the salts (chiefly metallic chlorides) attached to the crystals, and if they are then again dissolved in water and heated with hydrated baryta, the oxide of zinc is precipitated, and carries with it the greater part of the adhering colouring matter. The oxide of zinc and the excess of baryta are then removed as carbonates, by passing a stream of carbonic acid through the solution; the filtered liquid which contains chloride of barium and the organic substance is evaporated to dryness in the water-bath; the residue is dissolved in spirit, and sulphuric acid added in order to separate the baryta; filtration is then requisite. The solution, in which sulphuric and hydrochloric acids, and the organic substances, are now contained, is boiled with oxide of lead, which removes the acids; and any excess of lead in the filtered solution is removed by sulphuretted hydrogen. On evaporating the filtered solution in a water-bath we obtain a white crystalline mass, neutral in its reaction, with a slightly bitter pungent taste, and easily soluble in water and alcohol. The addition of bichloride of platinum to the alcoholic solution causes no precipitate, but chloride of zinc throws

¹ Poggendorff's Annalen, lxxii. p. 602.

down a copious white deposit, which, on being dissolved in water and evaporated, reproduces the crystals of the zinc-compound exactly as they crystallized from the urine.

The pure organic substance gave, as the mean of several analyses:

		Calculated.
Carbon	-	39·3
Hydrogen	-	7·0
Nitrogen	-	34·0
Oxygen	-	19·7

Hence it may be expressed by the formula $C_8H_7N_3O_3$. Human urine emitted in the morning contains about 5% of this body.]¹

9. *Hydrochloric acid.* The presence of this acid is easily shown. A portion of urine is treated with a little nitric acid, and nitrate of silver is then added, which produces a tolerably abundant curd-like precipitate of chloride of silver.

10. *Sulphuric acid* is always present in healthy urine. On treating a portion with nitric acid, and then adding chloride of barium, a white precipitate or turbidity may be observed, which is due to the formation of sulphate of baryta.

11. *Phosphoric acid* is recognised by the addition of free ammonia to fresh urine; earthy phosphates are immediately precipitated. In order to demonstrate the presence of alkaline phosphates, lime water is added to urine from which the earthy phosphates have been removed by filtration; phosphate of lime is then precipitated. Or, after the sulphuric acid has been precipitated with a baryta-salt, ammonia may be added to the filtered fluid, upon which phosphate of baryta will be precipitated.

12. *Silicic acid.* The only method of detecting the existence of this acid is by evaporating the urine, incinerating the residue, dissolving it in water, treating the insoluble portion with hydrochloric acid, and incinerating the residue that still remains. In this way we obtain the silicic acid.

13. *Hydrofluoric acid*, or fluoride of calcium, occurs in very minute traces, and can only be recognised by operating on a very large quantity of urine. The precipitate thrown down by ammonia must be collected, washed, placed in a platinum or porcelain crucible, treated with sulphuric acid, and its action on glass observed.

14. *Soda.* This base is contained in large quantity in the urine, both as chloride of sodium and in combination with acids. Chloride of sodium and the lactates can be removed from the ash of the residue of the urine by spirit; the solution must then be evaporated, and on submitting the salt to the action of the blowpipe, the intensely yellow flame which indicates the presence of soda is perceptible. The presence of soda may be also shown in other ways. Upon treating urine evaporated to the thickness of a syrup with alcohol, the chloride of sodium will dissolve, and by spontaneous evaporation will in part crystallize in the form of octohedra, which are partially percept-

¹ Liebig's und Wöhler's Annalen, vol. 52, part 1.

ible even to the naked eye. These consist of a combination of urea, and common salt. Fig. 24 exhibits such octohedra, obtained from evaporated and filtered urine. When the evaporation is conducted rapidly, these forms are replaced by a series of crystals shaped like crosslets and daggers, and usually crenate at the margin. See fig. 24*. If urine is allowed to stand in a shallow vessel, until it has become decomposed, and a portion of the urine has evaporated, a crystallized salt will be found, in which prisms and octohedra can be recognised both with the naked eye and with the microscope. The rectangular prisms, fig. 25, exhibit the combination of phosphate of soda with phosphate of ammonia (*sal microcosmicum*.)

15. *Potash.* The presence of this substance is detected by dissolving the fixed salts in some hydrochloric acid, extracting them by alcohol, and adding to the alcoholic solution of chloride of potassium some bichloride of platinum: a yellow precipitate of chloride of potassium and platinum is deposited.

16. *Ammonia.* The presence of this substance cannot be very easily demonstrated in healthy urine, on account of the urea and the nitrogenous extractive matters which coexist with it, since the ordinary ammoniacal salts (the chloride of ammonium and the lactate of ammonia) are dissolved with the urea by alcohol; and since, moreover, urea develops ammonia when treated with either free potash or its carbonate in just the same manner as the ammoniacal salts. The following method appears to me to be the most appropriate: Evaporate the alcohol-extract of urine, dissolve a portion of it in water, and add a solution of caustic baryta. If ammoniacal salts are present, a strong odour of ammonia will be developed. Neither pure urea, nor the nitrate, on being similarly treated, gives off this ammoniacal odour.

[Healthy urine, according to Liebig,¹ contains only very minute or doubtful traces of ready-formed ammonia, and these traces probably pre-existed, in the food partaken of. Fresh urine evolves ammonia when treated with alkalies, but it yields no precipitate with bichloride of platinum. Dr. Schlossberger made certain experiments to this effect in the laboratory at Giessen; upon treating fresh urine with bichloride of platinum, and allowing the mixture to stand at rest during the night, crystals were formed in the urine, which, upon examination, manifested all the properties of chloride of platinum and potassium. The amount of ammonia formed in the healthy organism is likewise very minute, not being sufficient even to neutralize the acid from which proceeds the acid reaction of urine and of saliva. We cannot assume the presence of any ammoniacal salt in the urine of herbivorous animals, which contains fixed or alkaline carbonates.

Experiments for the determination of the amount of ammonia in the urine of healthy individuals may become of importance in judging of pathological states; for in fevers and other diseases the amount of ammonia in the urine increases considerably. It is possible that, by analyzing the urine, we may, in the increasing or decreasing

¹ Lancet, June, 1844.

amount of ammonia, obtain a measure for the alterations which take place in diseases. But the salts of potash, which are rarely absent, as well as the ammonia which is formed by the action of bichloride of platinum upon the organic constituents of urine, render this reagent (the bichloride of platinum) very unsafe for determining the increasing or decreasing amount of ammonia in the urine during disease. The magnesia salts would, perhaps, answer this purpose better; the determinative examinations made with salts of magnesia are inferior to those made with bichloride of platinum, but they are exact enough for the purpose of comparison.]

17. *Lime.* There is no difficulty in proving the existence of lime in the urine. On adding oxalate of ammonia to fresh urine, a nebulous turbidity of oxalate of lime is formed. If the urine is somewhat concentrated by evaporation, a precipitate is obtained which appears under the microscope as an amorphous mass.

When urine is allowed to stand till ammonia is developed, phosphate of lime and ammoniaco-magnesian phosphate are precipitated. The phosphate of lime may be recognised under the microscope as an amorphous mass: sometimes, but rarely, it occurs in a crystalline form. Both varieties are exhibited in fig. 26.

18. *Magnesia.* The lime having been precipitated as an oxalate, and free ammonia added to the filtered urine, ammoniaco-magnesian phosphate will then be deposited. We have already observed that this salt becomes spontaneously formed, if urine is allowed to stand for some time, in consequence of the development of ammonia. A thin film may then be seen on the surface, in which we may detect minute crystals, even with the naked eye. The inner surface of the vessel is also covered with a crop of similar crystals. Under the microscope the ammoniaco-magnesian phosphate may be recognised by the peculiar crystalline form represented in fig. 27.

19. *Peroxide of iron.* The amount of iron contained in the urine is frequently very minute, and can only be detected in the ash, which must be dissolved in hydrochloric acid. Upon the addition of ferrocyanide of potassium to the acid solution, a deep blue colour, or a very slight precipitate of prussian blue is produced: while the addition of hydrosulphate of ammonia or infusion of galls effects a dark colouring.

QUANTITATIVE ANALYSIS OF THE URINE.

Method of separating all the proximate constituents.

An exact quantitative determination of all the constituents of the urine is a task beyond the powers of animal chemistry in its present condition. Our ignorance of the proximate constituents of the extractive matter, and our inability to separate them, are alone sufficient to preclude the hope of a perfect analysis: we must therefore content ourselves with pursuing the same course as we have already done with the blood, and must rest satisfied with effecting the sepa-

ration (as accurately as we can) of those constituents which at present we regard as the most important, and which present no peculiar chemical difficulty; whilst others, as for instance the various extractive matters, must be associated in groups.

Even this abbreviated and comparatively simple method does not yield absolute estimates, only a few of the constituents of the urine, as, for instance, the fire-proof salts, yielding quantitative results with analytical exactness: the determination of the organic constituents,—of the urea, uric acid, ammonia-compounds, and extractive matters is more or less insecure and fluctuating, and we must regard a quantitative analysis of urine as giving us certainly an idea of its probable constitution, but not by any means of its actual composition.

I shall now explain a method of analyzing the urine, by which the principal constituents may be isolated and determined.

It is impossible to estimate the various constituents of the urine from a single portion; different portions of the same urine must be used for the determination of the various constituents, as will be presently shown.

The urine to be examined must be tested with litmus paper, in order to ascertain the presence or absence of free acid. Healthy urine is generally acid, seldom neutral. If the urine is turbid, it must be examined under the microscope; the presence of mucus can be the only cause of turbidity in healthy acid urine. The specific gravity of the urine is best estimated by the 1000-grain bottle.

The quantity of urine to be analyzed must be carefully weighed, or the amount contained in the 1000-grain bottle (the contents of which are exactly known when the stopper is inserted,) may be taken. A small portion always adheres to the glass upon pouring it out, the quantity of which can be ascertained by weighing.

1. Determination of the free acid.

A known quantity of warm urine must be treated with tincture of litmus in which the excess of free alkali has been neutralized by acetic acid, so as to leave a perceptible red tint. Dilute solution of ammonia must then be added by drops, and with constant stirring, until the red colour begins to merge into a blue. The quantity of ammonia required for this purpose is estimated by weight, or, if a graduated vessel is used, by measure. From our knowledge of the quantity of ammonia in the solution, we can estimate the quantity of free lactic acid.

2. Determination of the water and vesical mucus.

From 500 to 1000 grains of urine must be filtered; the mucus which remains on the filter must be washed with water, dried, and weighed with the filter, the weight of which should have been previously determined. The filtered urine must be evaporated in the water-bath to the thickness of an extract, and then placed (in its

basin) in a receiver over sulphuric acid, in order to be thoroughly dried. The residue when dried must be weighed with the basin, and the water estimated by the loss of weight.

3. *Determination of the urea.*

The dry residue of (2) is moistened with sufficient quantity of water to reduce it to a uniform extract; it is then thoroughly exhausted with alcohol of 0·83; the alcoholic solution is evaporated in the water-bath to a state of dryness, and the residue extracted with anhydrous alcohol. The anhydrous alcohol is evaporated at a very gentle temperature; the residue is dissolved in a little water, and cold nitric acid (perfectly free from nitrous acid) added to it. The basin is then placed for some hours in snow, or in an artificial freezing mixture. The moist nitrate of urea is collected upon a filter, which is enveloped in the folds of thick blotting-paper, and pressed, as long as fresh blotting-paper continues to absorb moisture. The filter, which, with its contents, is now nearly dry, is exposed to a temperature of from 104° to 122°, and then quickly weighed. The known weight of the filter is deducted from the weight of the filter and its contents, or, which is better, the nitrate of urea is separated very carefully from the filter, again dried, (since it readily absorbs moisture,) and weighed. From the nitrate we estimate the quantity of urea.¹ (See p. 53.)

4. *Determination of the uric acid.*

Three or four ounces of urine must be treated with three or four drachms of hydrochloric or nitric acid, and allowed to rest for from 36 to 48 hours. Uric acid crystals of a whitish-gray, or more commonly of a red colour, deposit themselves from this acid urine, partly at the bottom, and partly on the sides of the glass. The mass of the clear supernatant fluid must be poured off, the crystalline coating is then loosened from the sides of the vessel, and collected on a small filter.

¹ [Marchand has recently examined the combinations of urea and nitric acid, and has arrived at conclusions very different from those of other observers. He used nitrate of urea, which was precipitated from its solution by the addition of nitric acid. It was pressed between folds of bibulous paper, and dried at 240°. Its aqueous solution was digested with carbonate of baryta, and the nitrate of baryta decomposed by sulphuric acid. The nitric acid amounted to 60·66 per cent.; hence the compound consisted of $C_2H_4N_2O_8 + 2NO_3 + HO$. A portion was heated to 284°; it then yielded a quantity of sulphate of baryta corresponding to 65·72 per cent. of nitric acid. It had probably become anhydrous, for in that state it would contain, by calculation, 64·3 per cent. As the neutral nitrate of urea was not contained in this manner, Marchand dissolved the acid compound in water, and added urea. The dried crystalline compound now obtained contained 55 per cent. of nitric acid, and was therefore composed of $2C_2H_4N_2O_8 + 3NO_3 + HO$.

When the liquid from which the above-mentioned salt crystallized was treated with urea and the solution again crystallized, he obtained a compound which lost no weight at 230°, and after being exposed for some time to this temperature, contained 44·1 per cent. of nitric acid. He concludes by observing that the compound usually separated in analyses does not contain the amount of urea stated in the text, but only 33·89 per cent. Marchand further states that crystallized oxalate of urea contains three atoms of water, two of which (14·6 per cent.) escape at 248°, while the third is retained till decomposition ensues. (Journ. für prak. Chem. Feb. 1845.]

When all the uric acid is collected on the filter, and the whole of the fluid has run through, a little water is sprinkled over it, and the filter is then dried and weighed. By subtracting the known weight of the filter, we obtain the amount of uric acid.

5. *Determination of the water and spirit-extracts.*

From 1000 to 2000 grains of filtered urine are evaporated on the water-bath, and the residue treated with alcohol of 0·83, which throws down the water-extract, as well as the sulphates and phosphates. These are collected upon a weighed filter, and washed with alcohol of similar strength. The filter with its contents is weighed, and by deducting the known weight of the filter, we obtain the weight of the water-extract and salts. By incineration of the filter and its contents, there are left only the sulphates and phosphates; the water-extract is, therefore, estimated by the loss.

Whatever is dissolved by the alcohol of 0·83 is mixed with the spirit used for washing, and the fluid gently evaporated on the water-bath until an extract-like residue is left; this, after being allowed to cool, (during which process it usually becomes solid,) is treated with cold anhydrous alcohol. In this way the spirit-extract, as well as chloride of sodium, and a portion of the alkaline lactates, if any are present, are separated. The basin is kept as cool as possible, and repeated additions of absolute alcohol are made, in order to see whether the alcoholic solution which has become clear after settling, still becomes turbid, and if so, a certain quantity of anhydrous alcohol must again be added. When the alcoholic fluid (A) is perfectly clear, it is decanted from the residue of salts, which is washed with anhydrous alcohol, cautiously dried on the water-bath, weighed, and estimated as spirit-extract with salts. By a thorough incineration we can determine the spirit-extract by the loss of weight. The following salts remain: chloride of potassium, chloride of sodium, and carbonate of soda; the latter corresponding with the lactates.

6. *Determination of the alcohol-extract, the lactate of ammonia, and chloride of ammonium.*

These are the most difficult constituents to determine. I proceed in the following manner: the alcoholic fluid (A) obtained from the precipitation of the spirit-extract, is evaporated on the water-bath to the consistence of a thick syrup, and after being thoroughly dried over sulphuric acid in a receiver, is weighed. The residue is dissolved in a little water, and free baryta gradually added, a gentle warmth being kept up as long as it continues to dissolve, and as long as ammonia is perceptibly evolved. This point being attained, the mixture is evaporated to the consistence of an extract, and moistened with a little alcohol of 0·83; a large quantity of anhydrous alcohol is then added, and the whole allowed to clear itself. There remain un-

dissolved, chloride of barium, a compound of baryta with extractive matter, and the greater part of the free baryta, which has probably been added in excess. Dissolved in the alcohol are urea, lactate of baryta, and a small quantity of free baryta. The undissolved portion is burnt in a platinum crucible, the residue incinerated, and the ash digested in water. The solution must be filtered, slightly acidulated with nitric acid, and the chlorine then precipitated by nitrate of silver. The chloride of ammonium can be calculated from it.

The alcoholic solution must be evaporated, the residue dissolved in water, the solution filtered, and a current of carbonic acid passed through it, until the free baryta is precipitated: it must then be again filtered, acidulated with nitric acid, and the baryta of the lactate of baryta precipitated by sulphuric acid. The lactate of baryta must be estimated from the residual sulphate.

By subtracting from the solid residue of the alcohol-extract the weight of the urea, of the free lactic acid, of the lactate of ammonia, and chloride of ammonium, we obtain the quantity of the alcohol-extract.

7. *Determination of the fixed salts.*

The determination of these constituents is of much importance; they are composed of potash, soda, lime, magnesia, sulphuric acid, phosphoric acid, and hydrochloric acid. The determination of the silicic acid would also be interesting, if a series of analyses in reference to this point were instituted. Iron, manganese, and fluoride of calcium exist in too minute quantities to be successfully determined, or indeed always detected. The bases and acids which were first named, viz. the potash, &c., may be determined in the following manner. Three or four ounces of urine are evaporated, and the residue incinerated. As the carbonaceous matter does not readily burn off, in consequence of being entangled with the melting salts, it is expedient to add some nitric acid to the urine, and to place a cover on the crucible. A white melted ash is soon obtained, the weight of which must be determined. A certain proportion of this ash, if the whole quantity is sufficiently large, may be weighed, and used for the determination of the chlorine, or a separate quantity of urine may be evaporated and incinerated for this purpose.

For the determination of the other constituents a known quantity of the salts is dissolved in water, to which a little nitric acid has been added; this solution (A) is filtered; what remains on the filter is silicic acid, mixed perhaps with a little carbon. It must be washed, burnt with the filter, and its weight estimated. The solution (A) and the water with which the contents of the filter were washed, are mixed together, and a slight excess of free ammonia added. The mixture is then warmed. By this means the earthy phosphates are precipitated, and, as in healthy urine the phosphoric acid is in excess as compared with the earths, the latter are completely thrown down. They are quickly washed, dried, exposed to a strong heat, and

weighed. In order to determine the quantity of lime in the earthy phosphates, they must be dissolved in very diluted nitric acid, and the free acid saturated with ammonia; the lime may then be precipitated by oxalate of ammonia. The filtered fluid will yield the magnesian salt, by precipitation with free ammonia.

The ammoniacal solution from which the earthy phosphates have been precipitated must be mixed with the water used for washing the precipitate, and supersaturated with nitric acid. A solution of chloride of barium must be added, as long as any sulphate of baryta continues to be precipitated. The fluid is then warmed, for the more perfect separation of the sulphate of baryta, which is collected on a filter, washed, exposed to a strong heat, and weighed. By this means the sulphuric acid contained in the urine is calculated. The acid solution from which the sulphuric acid has been precipitated is mixed with the water used for washing the precipitate in a stoppered bottle of such a size as to be nearly filled by it; it is rendered alkaline by caustic ammonia, and chloride of barium is added to it, as long as phosphate of baryta is precipitated. The bottle must be allowed to stand, with the stopper in it, until the precipitate is completely deposited. The fluid is then poured off, and the precipitate washed out on a filter with a little weak solution of ammonia. It is dried, exposed to a strong heat and weighed. The phosphoric acid must be calculated from the phosphate of baryta thus obtained. The ammoniacal fluid from which the sulphuric and phosphoric acids have been removed by baryta is mixed with the fluid with which the last precipitate was washed; they are evaporated, the residue treated with sulphuric acid, and then submitted to a high temperature to expel any excess of the acid. The fixed alkalies remain in combination with sulphuric acid. If these salts are dissolved in water, and chloride of barium added to the filtered solution as long as sulphate of baryta continues to be precipitated, the chlorides of potassium and sodium are left in the solution, from which they may be separated and estimated.

The chlorine is determined, as I have already remarked, by a separate experiment. A known quantity of the fixed salts is dissolved in water, and a little nitric acid added to the filtered solution; upon the addition of nitrate of silver, a curdy precipitate of chloride of silver is thrown down.

The proximate constituents of the fixed salts being thus determined, we have next to consider how they are combined. The sulphuric acid is associated with the potash, and if there is not a sufficient quantity of potash, with as much soda as will make up the deficiency: the rest of the soda is allotted to the hydrochloric and phosphoric acids. If there is more than sufficient potash to combine with the sulphuric acid, the excess is united with hydrochloric acid.

If the urine-salts froth very much upon being treated with an acid, and if we find that after combining the potash and soda with sulphuric, hydrochloric, and phosphoric acids some soda is still left, this

must be reckoned as lactate of soda. The earths occur as earthy phosphates.

The fixed salts may likewise be determined from the residue obtained in the investigation of the water- and spirit-extracts, (see 5,) by exposing it to a strong heat; and we are sometimes driven to this course of proceeding in consequence of having only a small quantity of urine to analyze. This method of determining the salts is, however, unsafe, in consequence of a portion of the lactate of soda being dissolved by the anhydrous alcohol, and because, farther, small quantities of the phosphates and sulphates are always associated with the chlorine-compounds. In adopting this method, we must determine the earthy phosphates and the alkaline sulphates and phosphates, from the water-extract; and the chlorine, with minute quantities of the sulphates and phosphates, from the saline residue of the spirit-extract.

In the determination of the urinary salts from the fixed residue, it becomes a matter of importance to ascertain whether the organic constituents do not contain a certain amount of sulphur and phosphorus, which increase the quantity of the sulphates and phosphates found after incineration. From an experiment, I am led to conclude that this is not the case. I determined the earthy phosphates, and the alkaline sulphates and phosphates, in three ounces of filtered healthy urine, and found earthy phosphates, 0·5; sulphate of potash, 2·45; phosphate of soda, 1·16. From the fixed salts of three ounces of the same urine I obtained, earthy phosphates, 0·52; sulphate of potash, 2·48; and phosphate of soda, 1·16.

A shorter method of separating the most important constituents of the urine.

Isolated and unconnected analyses of urine are of very little value in physiological and pathological chemistry. In proportion to the number of analyses made according to one uniform method, is the value of each individual analysis increased. It would obviously require an immense sacrifice of time and labour to institute a series of urinary analyses upon the plan that we have already laid down; our trouble will be much diminished by agreeing which of the constituents are to be considered as the most important, and devoting our attention to them alone. We do not by any means wish to imply that elaborate analyses, made on the system we have described, are not more valuable than those conducted according to a simpler scheme; we only wish it to be understood that a shorter method will give results that will fully answer many of our proposed ends.

A shorter method may be properly limited to the determination of the solid constituents of the urine, the quantities of urea and uric acid, of the fixed salts collectively, and, from them, of the earthy phosphates and alkaline sulphates and phosphates individually, and ultimately of the remaining constituents, as lactic acid, extractive matters, and the compounds of chlorine and ammonia.

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With this view we determine

- a. The specific gravity of the urine in the ordinary manner;
- b. The quantity of solid constituents, and of the urea, according to the method described in 2 and 3, from a weighed and evaporated portion of urine;
- c. The quantity of uric acid, according to the method given in (4,) by the addition of hydrochloric acid to a certain quantity of urine;
- d. The quantity of extractive matters and ammonia-salts, by evaporating a known quantity of urine and incinerating the residue. The amount of solid residue being known from b, we subtract from it the fixed salts which have been thus obtained as a residue after incineration, the urea (b), and uric acid (c); the difference corresponds with the extractive matters and ammonia-salts;¹
- e. The fixed salts are known by the weight of the residue in d; they may be easily burnt white by the addition of a little nitric acid. From these salts we can determine,
- f. The amount of earthy phosphates, and alkaline phosphates and sulphates, by the method described in 7.

ON THE COMPOSITION OF NORMAL URINE.

Berzelius² published an analysis of healthy urine in the year 1809, which was, till a very few years ago, the only one that gave a correct view of the constitution of so important a secretion. He does not state any thing about the circumstances under which the urine was voided, or in regard to the person from whom it was taken. 1000 parts contained:

Water	:	:	:	:	933-00
Solid residue	:	:	:	:	67-00
Urea	:	:	:	:	30-10
Uric acid	:	:	:	:	1-00
Alkaline acid, lactate of ammonia, alcohol, &c water-extract				}	17-14
Mucus	:	:	:	:	0-38
Sulphate of potash	:	:	:	:	3-71
Sulphate of soda	:	:	:	:	3-16
Phosphate of soda	:	:	:	:	2-94
Biphosphate of ammonia	:	:	:	:	1-65
Chloride of sodium	:	:	:	:	4-45
Chloride of ammonium	:	:	:	:	1-50
Phosphate of lime and magnesia	:	:	:	:	1-00
Silicic acid	:	:	:	:	0-03
					Fixed salts. 15-29

I have made two analyses of the urine of a healthy man, aged 33 years, of a decidedly sanguineous temperament, whose digestion and nutrition were not very good. 1000 parts contained:

¹ This estimate must be always rather too high, in consequence of the alkaline lactates being converted into carbonates in the process of incineration.

² Thierchemie, p. 458.

This includes the lactate (carbonate) of soda and a little sulphate of potash.

		Analysis 93.	Analysis 94.	
Specific gravity	.	1011	1012	
Water	-	963-20	966-00	
Solid residue	.	36-80	44-00	
Urea	-	12-46	14-578	
Uric acid	.	0-52	0-710	
Alcohol extract, with free lactic acid	.	5-10	Ext. mat. & amm. salts.	
Spirit extract	.	2-60	5-590	
Water-extract and vesical mucus	1-00	$= 10-14$	$= 12-94$	
Lactate of ammonia	.	1-03	2-550	
Chloride of ammonium	.	0-41		
Chloride of sodium	.	5-20	17-280	
Sulphate of potash	.	3-00	3-508	
Phosphate of soda	.	2-41	9-330	
Phosphates of lime and magnesia	0-58	11-19	0-654	13-77
Silicic acid	.	a trace	a trace	

I have analyzed the urine of the same man upon three other occasions under the following circumstances. *A* represents urine passed upon rising in the morning, after having drunk several glasses of water, the previous evening. After drinking coffee and a glass of water, such violent exercise was taken for two hours, that the pulse rose to above 100, with occasional intermissions; the urine *B* was then voided. Half an hour afterwards the urine *C* was discharged. In all three cases the urine was clear, *B* being the most slightly tinged. They all had an acid reaction, that of *C* being the strongest, and of *B* the weakest. The analyses, in which, however, all the proximate constituents were not determined, gave the following results:

		Analysis 95.	Analysis 96.	Anal. 97.
Specific gravity	:	1010	1008	1014
Water	.	972-600	981-000	957-600
Solid residue	.	27-400	19-000	
Urea	-	8-402	7-500	
Uric acid, extractive matter, ammonia-salts, and chlorine compounds	.	13-960	8-618	19-140
Phosphate of soda	.	1-650	1-200	2-750
Sulphate of potash	.	2-790	2-200	5-000
Phosphates of lime and magnesia	.	0-479	0-200	0-656

C. G. Lehmann has likewise made some very minute analyses of the healthy urine of a young well-fed man, [himself in fact.] These analyses approximate closely in their results to those of Berzelius. They were made with the collected urine of the past twenty-four hours. The concentration of the fluid may be explained by the circumstance of the young man by whom the urine was passed, taking only a very little drink, as is the usual habit with persons of the sanguineo-bilious temperament.

		1.	2.	3.
Water	-	937-682	934-002	932-019
Solid residue	.	62-318	65-998	67-981
Urea	-	31-450	32-914	32-909
Uric acid	-	1-021	1-073	1-098
Lactic acid	-	1-496	1-661	1-513
Water-extract	.	0-621	0-591	0-632

¹ See last note, preceding page.

Spirit and alcohol-extract	-	-	10.059	9.871	10.872
Lactates	-	-	1.897	1.066	1.732
Chlorides of sodium and ammonium	-	-	3.646	3.602	3.712
Alkaline sulphates	-	-	7.314	7.249	7.391
Phosphate of soda	-	-	3.765	3.666	3.869
Phosphates of lime and magnesia	-	-	1.132	1.157	1.106
Mucus	-	-	0.112	0.101	0.110

Christison¹ published an analysis of healthy urine, in which, however, he did not enter into very minute details. The specific gravity was 1029. In 1000 parts, he found 67.7 of solid residue, of which 55.2 were composed of urea, extractive matters, and lactates, 11.1 of alkaline chlorides, sulphates and phosphates, 1.0 of earthy phosphates, and 0.4 of mucus. Hence 100 parts of the solid residue contain about 40 urea, 16 fixed salts, 39 extractive matters and ammonia-salts, and 1.5 earthy phosphates.

Dumenil made an analysis of urine in 1826. He found the specific gravity of the mixed urine of several healthy persons to be 1016.

In 1000 parts there were 31.8 of solid residue, which consisted of 13.2 parts of urea not quite free from alcohol-extract, 0.08 of uric acid, 2.09 of extractive matter, 0.6 of earthy phosphates, 1.03 of phosphate of soda, 0.55 of phosphate of ammonia, 2.69 of sulphate of potash, 8.03 of chloride of sodium, 2.69 of sulphate of potash, 8.03 of chloride of sodium, 1.16 of chloride of ammonium, 0.18 of phosphate of lime, peroxide of iron, and sulphate of lime, and 0.39 of mucus.

[In addition to these analyses we may mention those of Becquerel, Marchand, and myself. Becquerel obtained the following results:

	Mean composition of urine of 4 healthy men.		Ditto of 4 healthy women.	General mean.
	Specific gravity	Water		
Water	-	-	1018.9	1015.12
Solid constituents	-	-	968.815	975.052
Urea	-	-	31.185	24.948
Uric acid	-	-	13.838	10.366
Fixed salts	-	-	0.391	0.406
Organic matters	-	-	7.695	6.143
			9.261	8.033

Marchand's³ analyses correspond very closely with those of Lehmann. He cites the two following analyses as representing the composition of the healthy secretion:

Water	-	-	-	-	933.199	938.856
Solid constituents	-	-	-	-	66.801	61.144
Urea	-	-	-	-	32.675	30.391
Uric acid	-	-	-	-	1.065	1.001
Lactic acid	-	-	-	-	1.521	1.362

¹ Edin. Med. and Surg. Journal, vol. 33.

² [These salts consisted of:

Chlorine	-	-	-	0.502
Sulphuric acid	-	-	-	0.855
Phosphoric acid	-	-	-	0.317
Potash	-	-	-	1.300
Soda, lime, and magnesia	-	-	-	3.944]

³ Lehrbuch der physiologischen Chemie, p. 292.

Extractive matters	-	-	-	-	11.151	10.553
Mucus	-	-	-	-	.283	.201
Sulphate of potash	-	-	-	-	3.587	3.201
Sulphate of soda	-	-	-	-	3.213	3.011
Phosphate of soda	-	-	-	-	3.056	2.998
Biphosphate of ammonia	-	-	-	-	1.652	1.231
Chloride of sodium	-	-	-	-	4.218	4.001
Chloride of ammonium	-	-	-	-	1.652	1.231
Phosphates of lime and magnesia	-	-	-	-	1.210	1.001
Lactates	-	-	-	-	1.618	1.032

The following table gives the mean result of six analyses of the morning urine of a healthy man, instituted by myself.¹

Specific gravity	-	-	-	1022.5
Water	-	-	-	961.00
Solid constituents	-	-	-	39.00
Urea	-	-	-	16.60
Uric acid	-	-	-	.61
Fixed salts	-	-	-	9.27
Organic matter and loss	-	-	-	12.07]

The apparent discrepancies in the composition of healthy urine, as shown in the analyses that have been quoted, depend for the most part on the fluctuating amount of water. If we calculate the proximate constituents of the urine in relation to an equal amount of solid residue, we shall find these differences exhibited in a much less striking manner, although to a certain degree they still exist.

100 parts of the solid residue of the urine contain—

	Berzelius.			Lehmann.			Simon.			Marchand.			Day.	
	1.	2.	3.	93.	94.	95.	96.	97.	1.	2.	3.	48.91	49.58	49.56
Urea	45.10	49.68	48.39	49.10	33.80	33.10	30.07	37.80	36.20	48.91	49.58	49.56		
Uric acid	1.50	1.61	1.57	1.63	1.40	1.60				1.59	1.63	1.58		
Extractive matter,														
ammonia-salts, {	36.30	28.95	25.80	29.54	42.60	46.00	50.90	47.90	47.37	32.49	31.74			
and chloride of sodium														
Alkaline sulphates	10.30	11.58	10.71	10.92	8.14	8.80	10.01	11.00	12.00	10.18	10.15			
Alkaline phosphates	{ 6.88	5.96	5.35	5.65	6.50	5.70	6.75	6.25	6.80	4.57	4.90			
Phosphates of lime, and magnesia	{ 1.50	1.97	1.73	1.65	1.50	1.50	1.75	1.46	1.62	1.81	1.63			

On the physiological relation of the urine.

[The following observations of Liebig on the influence of the salts contained in the food, upon the composition of the urine, are well worthy of consideration.

"The alkaline reaction of the lymph, chyle, and blood of man, and of the carnivorous animals, cannot be owing to the presence of a free alkali; for the nutriment of man, and of the carnivorous as well as the graminivorous animals, contains no free alkali, nor any salt formed of an alkaline base and an acid which might be destroyed in the organism, by the vital process, and thus cause the alkaline base to be liberated. The blood must contain the same salts as exists in the aliments. With the exception of common salt, nothing is added during the digestion of the aliments. We have seen that this sub-

¹ Lancet, Feb. 1844.

stance undergoes decomposition in the upper part of the digestive apparatus, being resolved into free soda and free hydrochloric acid; but we have also seen that the liberated soda rejoins the hydrochloric acid during the preparation of the chyme, and previous to the transformation of the latter into chyle;¹ that is, when the acid has performed its function, namely, the solution of the aliments; the salt formed by this combination, that is, common salt, has neither an acid nor alkaline reaction. The salts with an alkaline reaction contained in meat, flour, or grain, are alkaline phosphates. Hence it is obvious that the alkaline reaction of the chyle, lymph, and blood of animals feeding upon animal and vegetable substances, can only be derived from their alkaline phosphates.

"The bibasic phosphates of soda and of potash are, in many respects, highly remarkable salts; although of a tolerably strong alkaline reaction, yet they exercise no destructive action upon the skin or upon organic formations; they possess all the properties of the free alkalies without being such; thus, for instance, they absorb a large amount of carbonic acid, and this in such a manner that acids produce effervescence in a saturated solution of this kind, just as they would in alkaline carbonates; they dissolve coagulated casein, as well as coagulated albumen, into clear fluids, with the greatest facility, just as caustic or carbonated alkalies do. But of still greater importance in relation to the secretion of urine is their deportment towards hippuric and uric acids. Hippuric acid dissolves with the greatest facility in water to which common phosphate of soda has been added; uric acid possesses the same property at a high temperature; the phosphate of soda, in this process, loses its alkaline reaction completely upon the addition of uric and hippuric acids, and assumes an acid reaction. The acid nature of the urine of man, and of the carnivorous and graminivorous animals, is thus explained in a very simple manner.

"There are but two principal channels through which the salts entering the organism with the aliments can effect their exit from the body; viz., they must either be carried off in the faeces or in the urine. The most simple experiments show that soluble salts are carried off by the faeces only when the amount of salt contained in the fluids in the intestines is larger than that contained in the blood; if the amount of salt in these fluids is equal or inferior to that of the blood, the soluble salts are reabsorbed by the absorbing vessels of the intestinal tube, and enter the circulation, and are then removed from the body by the urinary organs and channels. If the amount of salt contained in the intestinal tube is larger than that contained in the blood, the salts exercise a purgative action.

"If, after previous evacuation of the rectum, a weak solution of common salt (one part of salt to sixty parts of water) be taken by means of a clyster, no second evacuation will take place; the fluid is absorbed, and all the salt is found in the urine. This experiment yields the most convincing results if ferrocyanide of potassium is sub-

¹ Liebig's Animal Chemistry, 2d edit. p. 112.

stituted for common salt; in this case, the first urine excreted after the injection of the saline solution, and frequently even after so short a time as fifteen minutes, contains so large an amount of ferrocyanide of potassium as to yield, upon the addition of persalts of iron, a copious precipitate of Prussian blue.

"The influence which salts in general exercise upon the secretion of urine is, in the highest degree, worthy of attention. It is a well-known fact that a very speedy emission of urine takes place, in healthy individuals, after drinking fresh pump-water. If ten glasses of water, of from six to eight ounces each, containing no more than 1-500th of its amount in salts, be drank at short intervals, an emission of urine of the usual colour will, after the lapse of about ten minutes, follow the second glass, and from eight to nine evacuations of urine will generally occur in the course of an hour and a half. The urine, in this experiment, emitted in the last evacuation, will be clear and colourless, like pump-water, and the amount of salts it contains is little more than is contained in pump-water. There are individuals who are capable of thus imbibing from six to eight quarts of water consecutively without any inconvenience.

"But the case is quite different with water possessing an amount of salts equal to that of the blood; if even as little as 1-100th part of common salt be added to pump-water, and from three to four glasses drunk, no evacuation of urine will take place, even two hours after drinking. It is almost impossible to drink more than three glasses of this saline water, for it weighs heavily on the stomach, as if the absorbent vessels had no power of taking it up. This obviously arises from the fluid within the channels of circulation, i. e. the blood, and the fluid without these vessels, i. e. the saline water, not exercising any physical action upon one another, i. e. not intermixing by endosmose or exosmose.

"Water containing a larger amount of salts than the blood, such as common sea-water, for instance, and even the weaker kinds of saline mineral waters, exercise again a different action from that of pump-water mixed with 1-100th of common salt; not only no emission of urine takes place after the imbibition of such saline water, but water exudes from the circulating vessels into the intestinal tube, and, together with the saline solution, is carried off through the rectum; purgation takes place, attended with much thirst, if the saline solution be in some measure concentrated.

"Considering that a certain amount of salts is absolutely necessary to constitute normal blood, we may deduce from these observations and experiments (which any one may easily imitate and verify upon his own person) that the physical condition of the tissues or of the blood-vessels opposes an obstacle to any increase or decrease of the amount of salts in the blood; and thus that the blood cannot become richer or poorer in salts beyond a certain limit.

"Fluids containing a larger amount of salts than the blood, remain unabsorbed, and leave the organism through the rectum; fluids con-

taining a smaller amount of salts than the blood enter into the circulation, absorb, and remove from the organism, through the urinary channels, all the soluble salts and other substances which do not belong to the constitution of the blood, so that, finally, only those substances remain in the organism which exist in chemical combination with the constituents of the blood, and which, therefore, are incapable of being secreted by the healthy kidneys.

"I have convinced myself, by careful and minute examinations, that urine emitted after drinking a copious amount of water, invariably contains a somewhat larger amount of salts than the water which has been drunk; whilst the amount of phosphates contained in the last emitted portions of the urine is extremely minute, and no longer detectible by the ordinary tests. It is therefore obvious that all the salts, without exception, contained in the urine, are to be considered as accidental constituents of the blood, which are excreted and removed from the organism precisely because they no longer form a part of the normal constitution of the blood. The phosphates emitted with the urine were, previously, constituents of substances which have been decomposed in the vital processes, or they existed as constituents of the blood, but upon its transformation into living tissues they were not admitted into their composition, not being required for their constitution.

"Now, among the products of the vital processes, which, together with the soluble phosphates, are removed from the organism through the urinary organs and channels, there are two organic acids, namely, *uric acid* and *hippuric acid*, both possessing the property of combining with the soda or potash of the alkaline phosphates, and acquiring in the combination a higher degree of solubility than they possess, *per se*, at the common temperature of the body. It is obvious that by the accession of these two acids, and by their action upon the phosphates of soda, a urate and hippurate of soda must be formed on the one hand, and an acid phosphate of soda on the other; and that, consequently, the urine must acquire an acid reaction.

But the presence of these two acids in the urine is not the only cause of its acid nature; there exists another cause which tends powerfully to maintain and increase it.

"According to the preceding remarks we ought to find in the urine all the soluble salts of the food, as well as a small amount of the phosphate of lime, which is soluble to a certain extent in acid fluids, together with magnesia. The amount of these latter substances will be in proportion to their solubility in acid phosphate of soda. The other insoluble salts of the aliments we ought to find in the faeces. In other words, assuming that the materials composing the aliments become converted into oxygen compounds, that is, are burnt in the organism, we ought to find in the urine all the soluble salts of their ashes, and in the faeces, all the insoluble salts. Now, upon comparing the constitution of the ashes of the blood or of the aliments, (or, rather, the salts contained therein,) with those of the

urine, we find that there exists a striking difference between their respective amount of sulphates.

"According to the analyses of the ashes of the grains of wheat and rye (Ann. der Chemie, vol. 46, p. 79,) the urine of an individual feeding exclusively upon bread, ought not to contain a trace of a sulphate, whilst the urine of an animal fed upon peas or beans ought to contain sulphates together with phosphates in the proportion of 9 of the former to 60 of the latter. Finally, as flesh contains no soluble alkaline sulphate (broth does not yield any precipitate of sulphate of baryta when tested with salts of baryta,) the urine of carnivorous animals ought to be equally free from soluble sulphates. We find, on the contrary, that the urine of man, according to the most correct analyses, contains a far larger proportion of sulphates than the aliments partaken of; nay, even that the amount of the sulphuric acid evolved from the system must, in many cases, be equal or superior to that of the phosphoric acid contained in the aliments. According to the analyses of human urine made by Berzelius and Lehmann, the amount of the sulphates present in urine is nearly double that of all the soluble phosphates together. Hieronymi found the amount of sulphate of potash contained in the urine of the tiger, the lion, and the leopard, compared with that of the phosphates, to be as 1 to 7½. It can be distinctly and positively proved that these salts have not been partaken of in such proportions. But we now know the origin of the greatest portion of the sulphuric acid contained in the urine; this acid has entered the organism with the food, not in the form of a sulphate, but as sulphur.

"Glutin¹, vegetable casein, flesh, albumen, fibrin, and the cartilages and bones, contain sulphur in a form quite different from the oxygen-compounds of this substance. This sulphur is separated as sulphuretted hydrogen during the putrefaction of these substances; it combines with the alkalies, which act powerfully upon these animal substances, and may be obtained from such combination in the form of sulphuretted hydrogen by means of stronger acids.

"Now, we know, from the experiments of Wöhler, that the soluble sulphurets become oxidized in the organism; and that thus, for instance, sulphuret of potassium becomes converted into sulphate of potash; and it is therefore unquestionable that the sulphur of the constituents of the blood, derived from the aliments, or, what comes to the same point, the sulphur of the transformed tissues, becomes finally converted into sulphuric acid by the oxygen absorbed in the process of respiration, and thus that in the urine it must appear in the form of sulphates; and from this cause the original amount of these salts contained in the aliments become increased. The alkaline base which we find in the urine, in combination with this sulphuric acid, is supplied by the soluble alkaline phosphates; and the latter,

¹ Dietrich (in the laboratory of Giessen) has examined gluten with regard to its amount of sulphur: he found wheat-gluten to contain from 0·033 per cent. to 0·035 per cent. of sulphur, exactly the same proportion as is contained in albumen or fibrin.

in consequence of the loss of part of this base, are converted into acid salts.

"It follows, from all we have hitherto stated, that the acid nature of the urine of carnivorous animals, as well as that of man, depends upon the nature of the bases partaken of in the aliments, and upon the particular form of their combinations. In the flesh, blood, and other parts of animals, as well as in the grains of the cereal and leguminous plants, there exists no free alkali. The alkali which these substances contain is invariably combined with phosphoric acid: the acids formed in the organism by the vital process, namely, sulphuric acid, hippuric acid, and uric acid, share the alkali amongst them, and this, of course, must give rise to the liberation of a certain amount of phosphoric acid, or what comes to the same point, to the formation of a certain amount of acid phosphates of soda, lime, and magnesia. The proportional amount of the liberated phosphoric acid varies with the temperature; at a higher temperature the phosphate of soda dissolves a larger amount of uric acid and hippuric acid than at a lower temperature,—at 100° more than at 60°. It is owing to this, that urine, upon refrigeration, sometimes deposits uric acid, or urate of soda in a crystalline state, which, of course, can only take place by the uric acid, at a lower temperature, restoring to the phosphoric acid the soda or potash which, at a higher temperature, it had withdrawn from it. At the common temperature phosphoric acid decomposes urate of soda, whilst, at a higher temperature, uric acid decomposes phosphate of soda. When urine, containing uric acid and manifesting an acid reaction, forms no sediment upon cooling, it shows that the amount of the phosphoric acid and that of the uric acid exactly balance each other with regard to their affinity for soda. Had there been present a larger proportion of uric acid, this would have separated upon cooling; whilst, on the other hand, the presence of a preponderating proportion of phosphoric acid would likewise have caused the precipitation of uric acid, because the affinity of the former for soda would then exceed that of the latter. This explains the circumstance that urine, in certain states, when, from some cause or other, its amount of sulphuric, hippuric, or other acid, becomes increased, precipitates a larger proportion of uric acid than urine in its normal state. The solubility of uric acid in urine must decrease in proportion as the amount of the other acids present in the urine increases, because those acids share the soda with the uric acid; and, of course, the larger the amount of soda which combines with these other acids the less comes to the share of the uric acid. It is likewise owing to this, that uric acid is very frequently precipitated from urine upon the addition of mineral or other acids, and that urine of a turbid whey-like appearance, from the presence of uric acid, frequently manifests a far more strongly acid reaction than normal urine.

"Now, bearing in mind that the use of alkaline citrate, of neutral tartrate of potash, bi-tartrate of potash, acetates of potash and soda, and tartarized soda, renders the urine alkaline by creating in it an

amount of carbonated alkali; and that, likewise, after the eating of fruit, such as cherries, strawberries, &c., the urine is of an alkaline nature, inasmuch as these fruits contain alkalies combined with vegetable acids, it is obvious that the acid reaction of healthy urine is purely accidental, and that urine of an alkaline or neutral reaction cannot be considered as a symptom of the diseased condition of the body. All the vegetable aliments, without exception, tubers, roots, and leaves, potatoes, turnips, greens, &c., contain alkalies in combination with vegetable acids: potatoes, for instance, contain alkaline citrates; turnips, alkaline racemates and oxalates, &c. All these plants yield, upon incineration, more or less strongly alkaline ashes, the bases of which were contained in the living plants, as salts of vegetable acids.

"It is obvious that by adding these vegetables to a meat diet, to bread and to other aliments prepared from flour, the nature of the urine must become thoroughly altered; for the alkalies which these vegetables contain in combination with organic acids, enter the urine, in the form of carbonated alkalies, and neutralize the acids, of whatever kind, which may be present. When partaken of in a certain proportion, they render the urine neutral; when partaken of in a larger proportion, they impart to it an alkaline reaction.

"The urine of all animals feeding upon vegetables, such as grass, herbs, roots, &c., has an alkaline reaction. The urine of the horse, of the cow, of the sheep, of the camel, of the rabbit, of the guinea-pig, of the ass, &c., is alkaline; it contains alkaline carbonates, and acids produce in it a lively effervescence.

"The acid, neutral, or alkaline reaction of urine of healthy individuals does not depend upon any difference in the processes of digestion, respiration, or secretion, in the various classes of animals, but upon the constitution of the aliments, and upon the alkaline bases which enter the organism through the medium of these aliments. If the amount of these bases is sufficiently large to neutralize the acids formed in the organism, or supplied by the aliments, the urine is neutral; whilst it manifests an alkaline reaction when the amount of alkaline bases thus supplied to the organism is more than sufficient to neutralize the acids; but in all these cases the urine accords with the nature of the aliments taken.

"The inorganic bases and acids contained in the urine were, with the exception of sulphuric acid, which joins them in the organism, constituents of the aliments. The amount of inorganic bases and acids emitted through the urine in twenty-four hours must, in adult individuals, be equal to that of these bases and acids supplied to the organism during the same period, through the medium of aliments."¹

Our knowledge respecting the influence of diet on the composition of the urine has been much increased by the admirable researches of

¹ *Lancet*, June, 1844.

Lehmann,¹ instituted on himself. The whole of the urine passed in twenty-four hours was always collected, the absolute weight and specific gravity determined, as well as the amount of solid residue. The investigation was commenced in October, and the amount of drink was only just sufficient to allay thirst. During thirteen successive days, on which he lived on his ordinary mixed diet, the following observations were made:

Amount of urine in 24 hours. grammes ²	Spec. grav.	Solid residue per mille.	Whole amount of solid residue, in grammes.
1088	1017·4	58·432	63·5718
898	1022·2	65·998	59·2663
927	1025·1	67·842	68·8895
1022	1024·7	66·744	68·2124
712	1020·2	79·923	56·9052
1361	1020·2	65·008	78·4759
900	1019·2	62·318	56·0863
940	1022·5	66·423	62·4376
1100	1019·1	61·984	68·1824
939	1029·4	80·878	75·9434
1448	1016·7	56·264	81·4703
1088	1025·2	67·981	73·9633
1328	1015·6	55·932	74·2777

A perfect analysis of the urine was made on three of these days, the results of which are recorded in p. 403.

The amount of urea was determined on the 1st, 2d, 4th, 6th, 7th, 8th, 11th, and 12th days. The results are given in the following table:

Solid residue in 1000 parts of urine.	Urea in 1000 parts of urine.	Urea in 100 parts of solid residue.	Daily amount of urea, in grammes.
58·430	26·72	45·74	39·077
65·988	32·91	49·87	29·556
66·744	28·22	43·79	20·869
65·008	29·25	44·99	35·306
62·318	31·45	50·46	28·301
66·423	29·50	44·41	27·728
56·264	23·72	42·15	34·339
67·981	32·91	48·41	35·804

From these data it appears that, during his ordinary mixed diet, the urea amounted on an average to 46·23% of the solid residue, and that the average amount of urea excreted in twenty-four hours was 32·498 grammes, or about 500 grains.

The amount of uric acid was determined on the 2d, 6th, 7th, 8th, 11th, and 12th days. The following results were obtained:

Uric acid in 1000 parts of urine.	Uric acid in 100 parts of solid residue.	Daily amount of uric acid in grammes.
1·073	1·626	0·967
1·124	1·729	1·357
1·021	1·638	0·919
1·097	1·651	1·031
1·131	2·001	1·630
1·098	1·615	1·195

From these numbers it appears that 1000 parts of urine contain, on an average, 1.089 of uric acid; and that 100 parts of solid residue

¹ Journal für praktische Chemie, 1842, 3.

² The gramme = 15·4 grains troy.

contain 1.71 of uric acid; likewise, that the daily amount of excreted uric acid is 1.183 gram., or about 18.3 grains. Hence the daily amount of urea is to that of uric acid as 27 : 1.

The mean amount of free lactic acid, (or, at least, the substance regarded by Lehmann as lactic acid,) in 1000 parts of urine was 1.525; and in 100 parts of solid residue, 2.325. The mean daily amount was 1.534 gram., or 23.6 grains.

The mean amount of combined lactic acid in 1000 parts of urine was 1.160; and in 100 parts of solid residue, 1.703. The mean daily amount was 1.173 gram., or 18 grains.

Having thus determined a standard of comparison, he proceeded to notice the effect of a purely animal diet on the urine. He lived for twelve days on a purely animal diet, and for four of these days entirely on eggs, during which period he consumed 128, or 32 a day. From an analysis of the eggs it appeared that he took daily 189.7 grammes of dry albumen, free from ash, and 157.48 grammes of fat; and from Scherer's analyses it appears that this albumen contained 104.335 grammes of carbon, and 30.16 grammes of nitrogen; while the fat contained 124.41 grammes of carbon. Hence the whole amount of carbon was 228.75 grammes, a little within the amount given off in the course of twenty-four hours, according to Liebig. The observations were conducted for twelve successive days in July, and yielded the following results:

Absolute weight of urine in 24 hours, in grammes.	Spec. grav.	Solid residue in 1000 parts.	Whole amount of solid residue, in grammes.
921	1029.2*	80.87	79.34
1240	1021.9	66.12	81.99
998	1030.7	84.23	84.06
1075	1027.8	77.72	83.55
1184	1026.4	72.30	85.61
1384	1018.7	59.21	82.09
1113	1028.5	78.15	86.09
1093	1028.9	79.04	86.23
979	1033.8	90.68	88.78
1211	1026.3	72.38	87.85
1346	1024.3	66.73	89.84
1127	1029.0	78.38	88.38

If we compare the mean of these numbers with the mean of the former corresponding table, we have:

	During a mixed diet.	During animal diet.
The absolute weight of the urine in 24 hours	1057.8 grammes	1202.5 grammes
Specific gravity	1022.0	1027.1
Amount of solid residue in 1000 parts of urine	65.82	75.48
Sum of the solid constituents	67.82 grammes	87.44 grammes

Hence it appears that, during a purely animal diet, the amount of solid constituents is increased, while at the same time the amount of water is augmented by no less than 125 grammes, notwithstanding these experiments were made in June, and those with a mixed diet in October.

From the above data it appears that the solid matters discharged

by the urine during an animal diet amount to about one fourth the amount of dry nutriment.

The following are the principal changes in the urine induced by use of a strictly animal diet. It becomes pale, of a straw colour, limpid, and similar in appearance to the urine of the carnivora. On the addition of nitric acid, crystals of nitrate of urea were immediately produced. Uric acid was gradually deposited in large crystals. The reaction of the urine was always decidedly acid. Two analyses instituted with the urine passed on the 28th and 30th of July, (the 9th and 11th days of the experiment,) gave the following results:

			July 28th.	July 30th.
Water	.	.	909-33	933-27
Solid residue	.	.	96-68	66-73
Urea	.	.	53-79	41-65
Uric acid	.	.	1-41	1-18
Free lactic acid	.	.	2-85	1-64
Lactates	.	.	1-67	1-02
Extractive matter soluble in water	.	.	0-82	0-61
Extractive matter soluble in alcohol	.	.	4-50	3-94
Mucus	.	.	0-09	0-11
Chlorides of sodium and ammonium	.	.	5-37	3-46
Sulphates	.	.	11-51	7-08
Phosphate of soda	.	.	5-62	4-04
Earthy phosphates	.	.	3-79	2-70

The six following observations were made regarding the amount of urea:

	Urea in 1000 parts of urine.	Urea in 100 parts of solid residue.	Urea secreted in 24 hours, in grammes.
July 23d { (the 4th day of the experiment)	45-71	58-815	49-134
27th	46-67	59-043	50-913
28th	53-79	59-390	52-034
29th	46-19	63-611	56-085
30th	41-65	62-413	54-071
31st	50-36	64-388	56-657

From these numbers it appears, that during a purely animal diet, there is a mean daily increase of 20-7 grammes in the amount of urea. During a mixed diet, the relation of the urea to the other solid constituents = 100: 116, while on an animal diet it = 100: 69. The uric acid was estimated on the last four days of the experiment:

	Uric acid in 1000 parts of urine.	Uric acid in 100 parts of solid residue.	Daily amount of uric acid, in grammes.
28th July	1-41	1-554	1-371
29th	1-20	1-630	1-438
30th	1-18	1-764	1-665
31st	1-37	1-749	1-646

Hence, while the mean daily amount of uric acid during a mixed diet is 1-183 grammes, the amount is increased during an egg-diet by 295 of a gramme, an increase not sufficiently large to entitle us to suppose that a purely animal diet favours the formation of uric acid in the healthy organism. During a mixed diet, the proportion of uric acid to the other solid constituents = 1: 58-5, during an animal diet it = 1: 59-7; i. e. there is a relative diminution. The proportion of uric acid to urea during a mixed diet = 1: 27-0, during an animal

diet it = 1 : 32.7; consequently the uric acid is not by any means increased in the same proportion as the urea; and, indeed, it can hardly be regarded as produced from the protein-compounds in the same manner as the urea probably is.

The mean amount of free lactic acid excreted daily (as deduced from four analyses) was 2.167 grammes.

The earthy phosphates were determined daily from the 27th till the 31st of July, when the experiments were discontinued.

The following are the results obtained:

In 1000 parts of urine, in grammes.	In 100 parts of solid residue.	Daily amount in grammes.
3.09	3.913	3.374
3.72	4.102	3.642
2.99	4.134	3.632
2.70	4.046	3.635
3.13	3.994	3.530

Consequently, during a purely animal diet, 3.562 grammes of earthy phosphates are, on an average, discharged daily by the urine; while, during a mixed diet, the average quantity is only 1.13 grammes. If we estimate the amount of earthy phosphates in the albumen at 2%, the whole quantity consumed daily with 189.7 grammes of albumen, amounts to 3.794 grammes; consequently, much the greater part (namely, 3.562 grammes) is carried off by the urine, while the remaining .232 of a gramme is removed with the excrements, perspiration, &c.

During a mixed diet, a much larger amount of earthy phosphates was consumed without there being a corresponding increase in the urine, the greater part being removed by the intestinal canal. Generally speaking, the amount of excreted earthy phosphates exceeds the amount consumed, the excess, doubtless, arising from the oxidation of the phosphorus contained in the protein-compounds during the metamorphosis of the tissues. This view is confirmed by the preceding observations; for, during the egg-diet, the phosphorized fat contained in the oil of the yolk is conveyed into the fluids of the body, and, by the oxidation of its phosphorus, in addition to the phosphorus of the protein-compounds, the phosphoric acid of the phosphate of lime is generated, while only a portion of the earthy phosphates of the food is conveyed into the blood. Lime occurs in the blood in considerable quantity, being conveyed there by the water taken as drink, and combining readily with the free phosphoric acid. Moreover, a farther confirmation of this view is afforded by the fact of the increased excretion of phosphate of soda. During a mixed diet, the daily average is 3.673 grammes, while, during a purely animal diet, it amounts to about 5.217 grammes.

Lehmann next proceeded to investigate the effects of a strictly vegetable diet. The urine was examined daily from the 12th to the 23d of August; it was of a yellowish-brown rather than a yellow colour; it had a faint odour, and a decidedly acid reaction, which did not disappear for six or eight days. The morning urine was of a

dark brown colour, and rapidly deposited mucous sediment, after which there was a gradual separation of bright red crystals of uric acid. The following table contains the daily amount of urine and of its solid constituents, and the specific gravity:

Absolute weight of urine in 24 hours, in grammes.	Spec. grav.	Solid residue in 1000 parts.	Daily amount of solid residue, in grammes.
980	1028·9	67·60	66·25
765	1036·1	82·76	63·31
1050	1020·1	55·65	50·14
978	1025·7	60·13	58·61
1212	1016·4	50·01	60·61
817	1032·3	75·68	61·83
916	1026·8	63·09	57·79
720	1034·2	80·76	58·15
796	1029·8	70·90	56·44
931	1023·8	58·09	54·08
811	1028·6	67·01	56·35
802	1027·9	65·08	58·05

By taking the mean of these numbers we are enabled to construct the following table:

Amount of urine in 24 hours	On mixed diet.	On animal food.	On vegetable food.
Specific gravity	1057·8 gr.	1202·5 gr.	909 gr.
Solid residue in 1000 parts of urine	1022·0	1027·1	1027·5
Solid constituents in 24 hours	65·82	75·48	66·41
	67·62 gr.	87·44 gr.	59·23 gr.

The amount of urea was ascertained daily from the 17th to the 23d of August:

Urea in 1000 parts of urine.	Urea in 100 parts of solid residue.	Daily amount of urea, in grammes.
28·67	38·145	23·585
26·00	41·211	23·815
30·68	37·988	22·069
28·31	40·078	22·618
22·42	38·607	20·880
25·52	33·093	21·467
26·69	39·478	22·917

Hence, on an average, the urea amounted to 39·086 $\frac{1}{2}$ of the solid residue, and 22·481 grammes were daily excreted. The effect of diet on the urea may be seen by the following table:

Urea during a mixed diet	In 100 parts of solid residue.	Daily amount, in grammes.
" an animal diet	46·230	32·498
" a vegetable diet	61·297	53·198
	39·086	22·481

Consequently, during a vegetable diet, there is both an absolute and a relative diminution of urea.

The uric acid was determined on five occasions:

Uric acid in 1000 parts of urine.	Uric acid in 100 parts of solid residue.	Daily amount of uric acid, in grammes.
1·40	1·836	1·135
1·23	1·947	1·125
1·17	1·652	.933
1·01	1·743	.942
.89	1·489	.969

Consequently, the average daily amount (from these five analyses)

was 1.021 grammes; and, on comparing this with the previous data, we have:

		In 100 parts of solid residue.	Daily amount, in grammes.
Uric acid during a mixed diet	-	1.710	1.183
" an animal diet	-	1.674	1.478
" a vegetable diet	-	1.737	1.021

Hence the uric acid is scarcely affected by the diet.

From three analyses it appeared that 1.189 grammes of free, and 1.371 grammes of combined lactic acid were daily excreted during a vegetable diet; and associating these with the previous numbers, we have:

	During a mixed diet.	During an animal diet.	During a vegetable diet.
Free lactic acid	1.462	2.167	1.189 grammes
Combined lactic acid	1.162	?	1.371

Hence there is not any very appreciable effect produced on the amount of the lactic acid. The phosphates and sulphates were much the same as during a mixed diet.

The three following perfect analyses of the urine were instituted:

	Aug. 20th. (the 9th day of the experiment.)	Aug. 21st.	Aug. 23d.
Water	929.10	941.91	934.92
Solid residue	70.90	58.09	65.08
Urea	23.31	22.42	25.69
Uric acid	1.17	1.01	0.89
Lactic acid	1.55	1.01	1.35
Lactates	2.39	1.89	2.06
Extractive matter soluble in water	3.80	3.07	3.71
" " alcohol	17.84	13.78	15.77
Mucus	.12	.10	.10
Chlorides of sodium and ammonium	3.80	3.07	3.71
Sulphates	7.16	7.14	7.23
Phosphate of soda	3.54	3.68	3.74
Earthly phosphates	1.22	1.09	1.11

The following table shows how much the extractive matters are influenced by diet:

	Extractive matters In 100 parts of solid residue.	Extractive matters discharged daily.
During a mixed diet	16637	10489 grammes
" an animal diet	5.818	5.196
" a vegetable diet	29482	16499

Lehmann concluded his experiments with some observations on the influence of a strictly non-nitrogenous diet on the urine. These are the least satisfactory of the series, because the general health becomes so rapidly injured as to affect the results. His daily food consisted of about 400 grammes of starch, sugar, or gum, and 125 grammes of almond oil. The urine passed after this diet had been continued for twenty-four hours, had a brownish red colour, a slightly acid reaction, and became alkaline in twenty-four to thirty-six hours. The following analyses were made in the month of June, on the 2d and 3d day from the commencement of this course of diet:

		¹	²
Water	-	953.95	965.11
Solid constituents	-	46.02	34.69
Urea	-	15.92	11.08
Uric acid	-	.59	.54
Lactic acid and lactates	-	4.89	5.11
Extractive matter soluble in water	-	2.60	2.71
" " alcohol	-	5.32	8.78
Mucus	-	.11	.11
Chlorides of sodium and ammonium	-	2.74	1.14
Sulphates	-	3.25	2.98
Phosphate of soda	-	3.01	2.48
Earthy phosphates	-	1.00	.91

On the second day 977 grammes, and on the third 1113 grammes of urine were discharged, so that the whole amount was calculated as follows:

		On the 2d day. 44.524 grammes	On the 3d day. 38.636 grammes
Solid constituents	-		
Urea	-	18.484	12.332
Uric acid	-	.869	.601
Lactates	-	4.865	5.687
Extractive matters	-	10.864	12.844

In conclusion, the following table gives the mean daily amount of the various solid constituents during these different systems of diet:

	Mixed diet.	Animal diet.	Vegetable diet.	Non-nitrogenous diet.
Solid constituents	67.62	67.44	59.24	41.68 grammes
Urea	32.50	53.20	22.48	15.41
Uric acid	1.18	1.43	1.02	.73
Lactic acid and lactates	2.72	2.17	2.68	5.62
Extractive matters	10.49	5.20	16.50	11.65

Lehmann¹ has likewise examined the effect of severe bodily exercise on the urine, and has found that the urea, lactic acid, phosphates, and sulphates are increased, while the uric acid and extractive matters are diminished. The following are the mean results obtained from the frequent examination of the daily urine during a pedestrian tour:

		In 24 hours.	In 1000 parts.
Water	-	900.006 grammes	916.707
Solid constituents	-	82.594	83.493
Urea	-	45.314	45.697
Uric acid	-	.642	.647
Lactic acid	-	3.140	3.166
Extractive matters	-	8.455	8.526
Alkaline phosphates	-	4.598	4.636
Alkaline sulphates	-	15.047	15.174
Earthy phosphates	-	1.105	1.114]

The admirable researches of Lecanu² show that the urine of the same person, analyzed at different times, gives nearly uniform results.

The urine of persons of different ages and sexes exhibits deviations both in the relative and absolute proportion of its constituents, while in persons of similar ages and sexes, the variations are very trifling.

The quantity of urine discharged by different persons, in the course of the twenty-four hours, varies considerably, even although the circumstances under which the observations are made are appa-

¹ Wagner's Handwörterbuch der Physiologie: Art. Ham. vol. 2, p. 21.

² Journal de Pharmacie, vol. 35, 1830.

rently similar. In 16 individuals of different ages and sex, with different but sufficient food, the quantity varied from 18 to 78 ounces.

The mean specific gravity of the urine of different persons varies. The highest specific gravity was 1030, the lowest 1016. It was most frequently between 1020 and 1030. The urine of men in the prime of life was more concentrated than that of old men, women, or children.

The quantity of urea, amounts, according to Berzelius and Lehmann, to nearly one half of the solid constituents; according to my observations, to a little more than a third. It follows, from the experiments of Lehmann, which have just been stated, that these proportions are dependent on the nature of the food; it is certain, however, that they are also dependent on the powers of assimilation, for we know that some persons thrive upon a very frugal, and barely sufficient diet; while others appear half-starved, although taking an abundance of nutritious food.

According to Lecanu, the quantity of urea which different individuals, living under different circumstances, secrete during the same period, differs greatly; it approximates, however, in proportion to the similarity of the circumstances.

In the course of twelve days there was secreted by—

A man aged 20 years,	334	grammes of urea
22	334	
38	310	
43	351	
53	364	
A woman aged 28	205	
16	210	
A child aged 8	171	
8	168	

The quantity of urea is greatest in men in the prime of life; it is greater in women than in old men, or children. It amounts in—

	Mean.	Maximum.	Minimum.
Men	432	509	357 grains
Women	294	436	153
Old men	125	189	60
Children aged 8	207	253	161
" 4	69	82	57

The quantity of urea excreted by the same individual in twenty-four hours, is always nearly the same; and if instead of twenty-four hours, we compare it for a longer period, the deviation will be still less marked.

The quantity of uric acid excreted in twenty-four hours by persons of different age and sex, and living under different circumstances, is as variable as the quantity of urea. It fluctuated between 1.38, and 24.25 grains. A comparison of the quantities of uric acid excreted during a longer period by persons of the same age, sex, &c., will show that they nearly coincide.

In twelve days there were excreted by—

A man aged 21 years	11.46	grainses of chloride
22	10.97	
23	13.04	

In eight days there were excreted by—

A girl aged 12 years	3.77	grainses of chloride
A woman aged 42	34.1	

The quantity of urine excreted by the same person during the same period (a period of some days for instance), is always nearly constant. This observation is confirmed by the analyses of Lecanu, and myself.

The amount of fixed salts, earthy phosphates, chloride of sodium, alkaline sulphates and phosphates, excreted in twenty-four hours varies considerably with age and sex. It fluctuated, in Lecanu's analyses, between 375 and 75 grains. There was apparently no uniformity in the amount of these salts in the urine of the same person during different equal periods. For instance, in a man aged 20, the amount of fixed salts in the urine of twenty-four hours, was determined four times. It varied from 345 to 224 grains.

In men, in the prime of life, the amount of fixed salts is higher than in aged persons, children, or women.

They occur, according to Lecanu, in the following proportions:

	Mean.	Maximum.	Minimum.
In men	260	373	153 grains
Women	222	312	166
Children of about 5 years	135	162	152
Old men	124	151	94

Lecanu found the earthy phosphates in the urine of twenty-four hours vary in different persons from 30.3 grains to rather less than half a grain.

The amount of earthy phosphates, excreted in twenty-four hours by the same person, is not always uniform; it appears to have no direct connexion with either age or sex.

In accordance with Guibourt and Rayer, Lecanu found these salts in smaller quantity in the urine of old men than in that of children. From the analyses made by Lecanu, Lehmann, and myself, it appears that the variations in the amount of earthy phosphates, both absolutely and relatively, are less than those of the other constituents of the urine.

A considerable difference was observed by Lecanu in the amount of chloride of sodium excreted by different persons. In his analyses the quantity excreted in twenty-four hours fluctuated between 116 grains and a quarter of a grain. Moreover, the quantity excreted by the same person in twenty-four hours is by no means constant. In four observations, each made on the urine of twenty-four hours, of a man aged 20, the maximum was 116, and the minimum 67 grains: in six similar observations on the urine of a man aged 35 years, the maximum was 82, and the minimum 29 grains. Lecanu found the quantity of chloride of sodium very small in the urine of women and old men.

It is clear that the excretion of a salt taken with most of our articles of food, must be entirely dependent on the quantity consumed, and must therefore vary very considerably. The urine, generally speaking, is deficient in salts during disease: our analyses show that the deficiency occurs at the expense of the chloride of sodium; the sulphates and phosphates taking only a small part in it. I have analyzed urine in typhus which contained a mere trace of chloride of sodium.

Lecanu observed differences similar to those we have just noticed in the alkaline sulphates and phosphates. The quantities excreted in twenty-four hours not only varied in different persons, but also in the same persons at different times. From my analyses, and those of Lehmann, it appears probable that a connexion subsists between the quantity of urea and of the sulphates, and possibly of the phosphates likewise; that is to say, the sulphates always increase with the urea, and *vice versa*. I incline, therefore, to the opinion of Berzelius, that at least a portion of the sulphates and phosphates owe their origin to the oxidation of sulphur and phosphorus, previously associated with protein which has become changed during the active metamorphosis of the blood. We do not, however, mean, in making this statement, to deny that the salts are also supplied to the blood by the food, and again separated by the kidneys.

The five following results, of much importance in physiology, have been deduced from the admirable researches of Lecanu:

1. The quantity of urea excreted by the same person during equal periods is constant.
2. The same is the case with respect to the uric acid.
3. The quantities of urea and uric acid excreted by different persons during equal periods are variable.
4. The varying amounts of urea excreted during equal periods by different persons, bear a relation to age and sex.
5. The amount of fixed salts varies in different persons without reference to age or sex. It also varies in the same person during equal periods.

An observation simultaneously made by Lehmann¹ and myself,² appears to me of high physiological import. We have ascertained that the amount of the urea, as well as of the sulphates, is increased by strong bodily exercise. I produced this state by taking such violent exercise for two hours that the pulse continued for some time above 100.

Farther confirmation of the above observation is certainly desirable.

If, however, we might assume it as a general fact, it would be an additional argument in favour of my view regarding the formation of urea; for it would then become still clearer that the urea is not formed during the change which occurs in the blood as a consequence of peripheral nutrition, but that it is formed during those processes which are dependent on the respiratory and circulatory functions, in

¹ See page 418.

² See page 403.

which we must seek for the greater part of the carbonic acid which is exhaled, and for the principal source of animal heat. I refer to the active metamorphosis of the blood, or to the mutual action excited by the blood-corpuscles, the plasma, and the oxygen held in solution in the blood, on each other.

[I am indebted to the kindness of Dr. Percy for the following analyses, which, to a certain amount, corroborate Simon's views.

The urine of a man, aged 30 years, training for a pedestrian match, was examined on two occasions: on the first, a quarter of an hour after running a mile in five minutes and a few seconds; on the second, after running three races of one mile each on the same day.

In both cases the urine was of a pale straw colour; it deposited a light mucous cloud on the first occasion, and was rather more turbid on the second. It was acid, and its specific gravity was 1019. It contained in 1000 parts:

		1.	2.
Water	- - -	956.00	950.80
Solid constituents	- - -	44.00	49.20
Urea	- - -	14.01	20.42
Uric acid	- - -	1.58	.64
Salts soluble in water	- - -	11.16	7.88
Salts insoluble in water	- - -	1.10	1.48

Although the soluble salts are not increased as in the cases of Lehmann and Simon, the augmentation of urea is very striking.]

To sum up once more: the urine is most abundant in urea, uric acid, and the most important salts, in men in the prime of life; it is less rich in these constituents in women; while the minimum occurs in old men and children. The nature of the food exerts an influence upon the composition of the urine; the amount of urea is increased by an excess of nitrogenous food, and diminished after living on food deficient in nitrogen. Upon a diminution of the quantity of food, the urine becomes deficient in nitrogen, as has been shown by my own experiments¹ and those of Lehmann; but the separation of nitrogenous compounds, as for instance urea, through the urine, occurs even when no food is taken. The urine is most abundant in urea and sulphates after active bodily exercise, in consequence, doubtless, of increased vascular excitement. The quantity of urine discharged in twenty-four hours, amounts on an average to about 45 ounces. It is more abundant in the prime of life than in old age or childhood, and in the male than in the female sex.

ON PATHOLOGICAL CHANGES IN THE URINE.

During disease the urine may undergo numerous modifications, both in its physical characters and its chemical constitution. The chemical changes may be reduced to one of the following forms.

1. One or more of the normal constituents of the urine existing in larger quantity than in healthy urine.

¹ Brande's Archiv. xxii. p. 25.

2. One or more of the normal constituents existing in less quantity than in healthy urine.
3. A normal constituent absent.
4. The presence of substances that do not exist in normal urine.

Qualitative and quantitative analyses of urine modified by disease.

In tracing the changes which the urine undergoes in disease, the simple addition of certain tests is sometimes all that is sufficient, while in other cases it is requisite to institute a quantitative analysis. I shall now proceed to describe these changes in accordance with the above scheme.

**INCREASE, DECREASE, OR ABSENCE OF THE NORMAL CONSTITUENTS
OF THE URINE.**

1. Increase or diminution of the solid constituents generally.

I have already observed that the proportion of the solid constituents to the water is so very variable, is so dependent upon the vicarious action of the skin and lungs, and upon the quantity of fluid that has been taken into the system, that it is impossible (without taking other facts into consideration) to determine from the urine alone, whether a mere increase or decrease of the solid constituents is due to diseased action. Pale urine, more or less like water, may be fairly considered deficient in solid matters, while a deep brown colour is indicative of an abundance of these constituents.

The specific gravity,¹ and still more the determination of the solid constituents in the manner which has been already described, will give the required information. The colour of the urine is sometimes deceptive, especially the fiery red that occurs during fevers. Urine of this sort is frequently found to be poorer in solid constituents, and its specific gravity lower than we should have anticipated from its colour: it is usually, however, more abundant in uric acid than normal urine.

2. Increase or decrease of free lactic acid.

With a little practice we may form a rough estimate of the increase of free acid, by observing the colour which the urine imparts to blue litmus paper. If neither the blue nor the red litmus paper is affected the urine is neutral.

3. Increase, decrease, or absence of urea.

In the course of my analyses, I have found that the quantity of urea may vary from 0.3% to 2.4% in fresh urine; I have observed, however, at the same time, that these statements are very deceptive, if the amount of solid residue is not at the same time given. It is

¹ The common urinometer is sufficiently accurate for ordinary cases.

only by comparing it with the solid residue that we can judge whether the urea has increased or decreased in an extraordinary manner. In healthy urine the urea may probably fluctuate from $\frac{1}{2}$ to $\frac{1}{3}$ of the weight of the solid constituents. Further experience is wanted to show whether an increase or decrease of this constituent (apart from other changes) implies a diseased state of the urine.

Urine has been known to yield crystals of nitrate of urea, a short time after the addition of nitric acid, without being first concentrated by evaporation. Indeed Lehmann observed that his morning urine, after living exclusively for five days on animal food, contained so much urea, as to stiffen immediately upon the addition of nitric acid. This might arise either from an absolute increase of urea, or from a relative increase, corresponding with an augmentation of the solid constituents generally.

An entire absence of urea has been observed in cases of diabetes insipidus, in which the urine is distinguished by an extreme deficiency of solid constituents: such statements should, however, be received with caution. Willis¹ instances such cases; he is, however, inclined to believe that it is always present in very small quantity. In order, therefore, to offer a decided opinion regarding either the absolute pathological increase or decrease of urea, it is requisite to estimate its weight, and the ratio of its weight to that of the solid constituents generally. The method of determining the urea is described at page 397. If the quantity of urea is so small as to render the crystallization of its nitrate imperceptible to the naked eye, the microscope must be used in the manner described when treating of the Blood, in page 154.

4. Increase, decrease, or absence of uric acid and the urates.

The variation in the quantity of uric acid in diseases has long been known, but it has not yet been determined with certainty whether this is in all cases an absolute, or whether in some cases it is merely a relative increase dependent upon the increased amount of solid constituents generally. The point must be determined by the quantitative analysis of uric acid, and its ratio to the solid constituents generally.

a. Increase of uric acid. Urine, containing an excessive quantity of uric acid, exhibits in most cases a very high colour, and has an acid reaction. Its specific gravity is frequently lower than would have been supposed from the intense colour.

If this urine is allowed to stand for some hours, there are deposited, partly at the bottom, and partly on the sides of the vessel, (and they are not frequently observed on the surface,) small crystals perceptible to the naked eye, whose form, under the microscope, usually appears as delineated in fig. 23*a*, sometimes as in fig. 23*b*. Vigla²

¹ Urinary Diseases and their Treatment. By Robert Willis, M.D. p. 12.

² Etude microscopique de l'urine, éclairée par l'analyse chymique. (L'Expérience, vol. I, p. 193.)

states, that in addition to the crystallized uric acid, a portion separates as an amorphous powder. It is only rarely that I have observed uric acid deposited in this amorphous form: the amorphous sediment of a yellow or reddish colour, which frequently occurs in large quantity in acid urine, may be shown to consist of urate of ammonia, by its ready solubility when the urine is warmed. Rayer, in his work on Diseases of the Kidneys, describes the crystalline form of uric acid, which is represented in fig. 23c.

As a further evidence that these crystals are composed of uric acid, they may be tested with nitric acid in the manner explained in page 382.

A brown or reddish-brown sediment is sometimes observed to be deposited in dark reddish-brown urine, which does not disappear either upon the application of heat or the addition of hydrochloric acid, and in fact in the latter case is rather increased. Under the microscope it exhibits the described forms of uric acid. We also observe, although more rarely, that dark urine will deposit a dense gray or yellow granular sediment, which is shown, by the application of heat, by the addition of hydrochloric acid, and by the microscope, to consist also of uric acid coloured by a peculiarly small quantity of uroerythrin. If the amount of uric acid is to be determined quantitatively in these instances, we must have regard not merely to the uric acid which is deposited, but also to that which remains in solution. The amount of the whole urine is determined as accurately as possible, the sedimentary uric acid collected on a weighed filter, washed with distilled water, dried, and weighed. Any uric acid that adheres to the glass, and cannot be removed by a feather or a glass rod, or by washing out the glass with water, must be treated with some warm solution of potash, until it is dissolved.

The alkaline solution must be filtered, and the uric acid precipitated by hydrochloric acid, collected on a filter, dried, and its weight ascertained. We thus estimate the ratio of the separated uric acid to the whole fluid and to the solid residue, if indeed this element has been determined from a weighed quantity of the urine. A certain quantity of the urine is treated with hydrochloric acid in the manner indicated in page 397, allowed to rest for twenty-four to forty-eight hours, and the precipitated uric acid collected on a filter and weighed. We thus obtain the amount of uric acid held in solution, and its ratio both to the whole amount of urine, and to the solid residue.

b. Increase of urate of ammonia. Urate of ammonia, which, as we have already mentioned in page 381, is probably an invariable constituent of urine, is occasionally excreted to a very large amount during the exacerbations of fever, arthritic attacks and various other diseases. It is the most common form of urinary deposit, but seldom occurs alone; it is frequently mixed with uric acid, sometimes with urate of soda or of lime, and occasionally, but not often, with earthy phosphates. Urine depositing urate of ammonia is generally of dark colour, is seldom clear, and usually exhibits an acid reaction; it is,

however, occasionally neutral or even alkaline. It is only in the latter case that earthy phosphates can be present, as they are never precipitated in urine with a marked acid reaction. The colour of urate-of-ammonia sediments varies from a yellowish to a brick-red tint. The red sediments frequently contain free uric acid, and sometimes urate of soda: nearly white sediments of urate of ammonia have occasionally been observed. Urate of ammonia seems to preponderate in the yellow and yellowish-red sediments, and free uric acid in those of a more purple-red colour.

All these sediments may contain more or less mucus.

1. If the sediment consists of urate of ammonia alone, it may be at once recognised by its perfect solution when the fluid is raised to incipient ebullition. To determine this point, the clear fluid is poured from the sediment, some of which is placed in a test tube and heated over the flame of a spirit-lamp: the fluid first becomes transparent on the surface, and gradually clears throughout its whole extent: on being allowed to cool, it again becomes turbid, and deposits the sediment afresh. If a portion of the sediment, after being washed, is rubbed with caustic lime, a perceptible odour of ammonia is developed: and if a few drops of nitric acid are poured over it in a porcelain basin, and gentle heat applied, the purple colour, indicating the presence of uric acid, appears. On heating a little of it on platinum foil, it burns away without a residue.

2. If uric acid is mixed with the urate of ammonia, the sediment sinks rapidly to the bottom, as a dense granular powder, after the fluid has been cleared by the application of heat. If hydrochloric acid is added, after the urate of ammonia has been dissolved by heat, the precipitate on cooling consists of uric acid alone.

3. If earthy phosphates are mixed with the urate of ammonia, the urine is either neutral or alkaline, and is only partially cleared by heat. The turbidity which remains, produced by the earthy phosphates in suspension, disappears immediately upon the addition of hydrochloric acid. Free uric acid is precipitated on cooling.

4. If mucus or pus is mixed with the urate of ammonia the fluid becomes only partially cleared on warming, neither does it become perfectly clear on the addition of hydrochloric acid, since mucus and pus are not dissolved by that agent. If there should be so large a proportion of mucus and earthy phosphates mixed with the urate of ammonia, that the solution of the latter salt on the application of heat produces no perceptible effect, it will only be necessary to filter the heated urine, and to allow it to cool. The separation of urate of ammonia on cooling renders it turbid, and crystals of uric acid may be obtained on the addition of hydrochloric acid.

5. If urine containing urate of ammonia is albuminous, it is necessary to be very cautious in the application of heat as a test. On gently warming the tube, the urate of ammonia dissolves before the albumen begins to coagulate. If the fluid which has thus become clear is exposed to a stronger heat, it becomes cloudy, the turbidity

commencing in the upper, hottest stratum of fluid, and gradually extending itself.

Urate of ammonia is recognised under the microscope as an amorphous mass, in which large, well-defined globules, sometimes united two and two, are often observed. Fig. 28 *a* and *b* exhibit these forms. It is obvious from a comparison of fig. 28 *a*, and fig 26, that the urate of ammonia, in consequence of its form, may easily be mistaken for phosphate of lime. The following points enable us to distinguish them. Phosphate of lime occurs as a sediment only in neutral and alkaline, never in acid urine. Phosphate of lime, when examined under the microscope, disappears instantaneously on the addition of a little hydrochloric acid, which usually develops numerous air-bubbles. The sediment of urate of ammonia does not disappear so rapidly under similar treatment, and in a short time, frequently only a few minutes, its place is occupied by rhombic crystals of uric acid, as shown in fig. 28 *c*.

The quantitative determination of urate of ammonia presents no difficulty when no other constituent is present in the sediment. The weight of the urine and the amount of solid residue are accurately determined: the sediment is collected in a filter of known weight, washed with a little ice-cold water, dried, and weighed. The ratios of the amount of sediment to that of the whole urine, and to that of the solid residue are thus obtained. In order to separate the urate of ammonia from uric acid, earthy phosphates, or mucus, with which it may be mixed, the sediment must be collected, and the quantity of urine from which it was deposited, carefully ascertained. The sediment must then be placed in a test-tube with a little of the urine, and gradually raised to the boiling point (if we are previously assured that no albumen is present:) it must then be filtered, and the residue washed with a little hot water, while the clear fluid that passes through the filter must be artificially cooled, and the urate of ammonia allowed to separate. It must be collected on a filter, dried, weighed, and its ratio determined in reference to the urine, and to the solid residue. The determination of the urate of ammonia as uric acid, from which the amount of the salt might be calculated would, perhaps, give safer results, since uric acid is less soluble than urate of ammonia.

The fluid which, by the application of heat, has taken up the urate of ammonia from the mixed sediment, must be concentrated by evaporation, and treated while still warm with hydrochloric acid. Upon cooling, the uric acid will separate and must be collected.

c. Increase of urate of soda. I am not certain whether urate of soda exists in normal urine. I shall, however, proceed to state in what manner its presence may be recognised in certain pathological conditions. Deposits of urate of soda alone are not often to be met with; this substance is, however, frequently associated with uric-acid and urate-of-ammonia sediments. Urate of soda is detected chemically in the same manner as urate of ammonia; like that salt it dis-

solves on the application of heat; and when warmed on a porcelain capsule with a little nitric acid, it develops the same purple colour. It differs, however, from that salt, in not developing an odour of ammonia when rubbed with caustic potash, and in leaving a white adhesive residue, when heated on platinum foil. This residue, when moistened with water, colours red litmus paper blue, and froths when treated with hydrochloric acid,—(carbonate of soda.) It may be distinguished in the same manner as the urate of ammonia from uric acid, earthy phosphates, mucus, or pus.

Under the microscope it presents the form of globules, mingled with small prisms arranged in stellar groups: at least it is in this form that I have always seen it when obtained artificially; and I have detected such globules, only of a more opaque appearance, in certain urinary sediments. These forms are exhibited in fig. 29 *a* and *b*. Certain forms described by Vigla and Quevenne are given in fig. 29 *c*. This peculiar crystalline arrangement is sufficiently characteristic to enable the urate of soda to be detected when mixed with urate of ammonia, or other sedimentary matters, either crystalline or amorphous.

For a quantitative analysis of a sediment consisting of pure unmixed urate of soda we must proceed in exactly the same manner as for urate of ammonia. If, however, it is mixed with uric acid, earthy phosphates, or mucus, the same method must be adopted as for urate of ammonia under similar circumstances. If urate of ammonia is mixed with urate of soda, they are both held in solution when the urine is warmed, and are thus separated from the other constituents of the sediment.

The solution is then slightly concentrated by evaporation, and afterwards thoroughly cooled. The alkaline urates separate themselves, are collected on a filter, dried, and weighed. If the filter with its contents is then incinerated in a platinum crucible, the urate of soda will leave carbonate of soda, which must be converted into a sulphate, and determined in that form. From the sulphate of soda we can reckon the urate, and by deducting the latter from the whole amount of alkaline urates, we obtain the amount of urate of ammonia.

d. Decrease of uric acid. A relative and an absolute decrease of uric acid has frequently been observed. In diabetes mellitus I have sometimes been unable to obtain any trace of it, while in other cases I have found it. If the method described in page 382 fails in yielding any traces of uric acid we are not justified in assuming its entire absence. In doubtful cases we must evaporate a large quantity of urine, and treat the residue with alcohol. The portion of the residue which is insoluble in alcohol must be dissolved in acidulated water, and there is then an insoluble residue left, consisting of mucus, silice, and uric acid (if this constituent be present.) If the nitric-acid test be then carefully applied, we may convince ourselves with certainty whether there is an entire absence of uric acid.

5. Increase or diminution of the extractive matters and ammonia-compounds.

An increase or diminution in the quantity of the extractive matters¹ of the chloride of ammonium, and lactate of ammonia, in pathological conditions of the urine can only be ascertained by the analytical proceedings described in pages 384 and 398.

6. Increase or diminution of the fixed salts.

The qualitative and quantitative variations occurring in the mixture of the fixed salts of the urine in disease are deserving of much attention. Some of these changes may be recognised without difficulty.

a. Increase or diminution of the earthy phosphates.

There are certain diseased states of the system in which the earthy phosphates are absolutely increased to a very marked degree; there are others, again, in which they decrease in an extraordinary manner, or even altogether disappear.

a. It is no very rare occurrence for the free acid of the urine to become neutralized by the formation of ammonia, and the urine thus becoming neutral or even alkaline, the earthy phosphates are precipitated. Urine in which these events occur is most commonly light-coloured; sometimes, however, dark. Blue litmus paper is not at all reddened by it, in fact red litmus is usually rendered slightly blue, and in some cases a powerful alkaline reaction is manifested. Generally speaking, the urine is clear and slightly acid at the period of its emission, but in a very short time it undergoes the change we have stated; a change which also occurs in normal urine, but not till after the lapse of several days. It becomes turbid, a film is formed on the surface in which minute crystals may be frequently detected with the naked eye. A sediment shortly begins to form, and at the same time the inner surface of the glass which contains the urine

¹ [At the meeting of the German Association of Natural Philosophers, held at Nuremberg last September, a paper was read by Scherer, on the extractive matters of the urine. The following are the principal facts he has ascertained. The greater portion of the extractive matters is merely a pigment analogous to those of the blood and bile. It may be thrown down from the urine by acetate of lead, and by treating the precipitate with alcohol and hydrochloric acid, it may be obtained in a state of purity. In healthy individuals it yields from 62 to 63 per cent. of carbon, and from 6·2 to 6·4 of hydrogen. In fevers, when there is rapid waste of tissue, and the functions of the lungs and liver are inactive, the carbon may amount to 66 or 67, and the hydrogen to 7·2 per cent. An increase in the quantity of extractive or colouring matter may be detected by boiling urine in a test-tube, and adding a little hydrochloric acid to it. Urine containing an excess of this colouring matter becomes of a dark colour, and on cooling deposits a brownish, blackish, or frequently an indigo-blue sediment, freely soluble in alcohol. Scherer believes that this colouring matter is formed from the haematin of arterial blood, and that the amount of carbon contained in this pigment varies inversely with the degree of oxidation of the blood; that its formation is analogous to the formation of uric acid and urea; that the carbon and hydrogen contained in it do not increase in an equal ratio; and that, finally, a long-continued secretion of urine, rich in this colouring matter, usually induces anaemia and emaciation. (Med. Times, Oct. 11, 1845.)]

becomes covered with a stratum of salts; at least I have observed this to occur in several instances. Sediments of this kind are sometimes scanty, sometimes very copious. I have seen a case in which the sediment, which consisted almost entirely of earthy phosphates, occupied, when it had entirely settled, one third of the volume of the fluid. I received from a physician of this city, a portion of dried urinary sediment which consisted almost entirely of pure earthy phosphates. This fragment bore evident traces of the form of the glass in which the urine had been kept, and it was of the extraordinary thickness of nearly an inch and a half. Earthy-phosphate sediments are seldom perfectly pure; their colour is white, gray, yellow, or reddish. White and gray sediments consist principally of earthy phosphates and mucus; yellow and reddish sediments contain a greater or less admixture with urates.

That the sediment is composed of earthy phosphates we are assured by the following chemical facts. The urine from which it is precipitated is neutral, or more commonly alkaline; the sediment does not dissolve on the application of heat, like the urates; it is, however, readily dissolved by the addition of an acid (hydrochloric, nitric, or acetic,) to the urine; a property which is not enjoyed by sediments of the urates, of mucus, or of pus. If the sediment contain so large a proportion of urates and mucus that the addition of an acid does not produce any obvious degree of clearing, the acidulated urine must be gently warmed and filtered from the insoluble constituents. Upon the addition of free ammonia to the clear, filtered fluid, the earthy phosphates will be precipitated.

The nature of the sediments may be still more quickly ascertained by the microscope. If the sediment consists of earthy phosphates, we observe the beautiful crystals of ammoniaco-magnesian phosphate depicted in fig. 27, and also amorphous masses of phosphate of lime, fig. 26. Upon the addition of a minute quantity of free acid to the objects on the field of the microscope the crystals and amorphous masses immediately disappear, and at the same time numerous air-bubbles are liberated. If the earthy phosphates have been dissolved by a little acidulated water from the urates and mucus or pus, with which they were associated, and are then precipitated from the filtered solution by free ammonia, the precipitate exhibits other forms under the microscope.

I have represented these forms, which seem to vary according to circumstances, in fig. 30. Fig. 30 *a* exhibits the different forms under which the ammoniaco-magnesian phosphate is precipitated, in which the predominating character is the forked arrangement of the crystals. Fig. 30 *b* exhibits the forms in which the phosphate of lime appears.

The quantitative determination of earthy-phosphate sediments presents no difficulty, if other constituents are not also present. The method of proceeding is exactly the same as for the quantitative determination of the urate-of-ammonia sediment in page 427. Its

amount must be determined in reference to the whole quantity of urine, and to the amount of solid residue.

In order to separate the earthy phosphates from urates, and mucus or pus, the sediment must be collected, washed with a weak solution of ammonia, the earthy phosphates taken up by water acidulated with hydrochloric acid, precipitated from the filtered solution by free ammonia, collected on a filter, dried, and weighed. Upon submitting the dried precipitate to a strong heat the ammonia is given off, and the weight proportionally diminished. The ratio of the earthy phosphates to the solid residue of the urine enables us to determine whether an increase in this particular class of constituents has occurred. If the relative quantities of phosphate of lime and ammoniaco-magnesian phosphate are required, the separation must be conducted on the principle described in page 399.

b. Diminution of the earthy phosphates. There can be no doubt that in certain diseases the earthy phosphates are much diminished, and that occasionally they altogether disappear. If the amount of earthy phosphates in the urine should be so slight that, upon the addition of free ammonia no precipitate is observed, it will be necessary, in order to be assured of the entire absence of this constituent, to evaporate a large quantity of urine, to incinerate the solid residue, to dissolve the ash in water containing a little nitric acid, and then to add ammonia. If no precipitate is formed after the fluid has been warmed and allowed to rest for some hours, the absence of earthy phosphates may be considered as proved.

b. Increase or diminution of the chloride of sodium and of the fixed alkaline sulphates and phosphates.

The quantity of fixed alkaline salts almost always decreases during disease, principally in consequence of the diminution of the chloride of sodium, which, however, is by no means one of the most important of the saline constituents, and whose weight may be determined in the manner described in page 401. It is different, however, with the alkaline phosphates and sulphates, which (more especially the sulphate of potash,) appear to fluctuate considerably in disease.

We may readily be convinced of the presence or of the total absence of the aforesaid salts in urine which has become modified by disease, by the application of certain tests, or by the methods which have been enumerated in page 393, under 9, 10, and 11; indeed the practised experimenter will be able to judge from the specific gravity whether there is any decided increase or diminution in the amount of the fixed alkaline salts.

As, however, it is of importance to know the exact amount of the alkaline sulphates and phosphates in certain diseases, we must adopt the method described in page 401, and determine the relation of these salts to the solid residue.

7. Increase of mucus.

In catarrhal affections of the bladder the amount of mucus in the urine is often very much increased. The urine in these cases is acid or neutral, but frequently exhibits a strong tendency to become ammoniacal in a short time. The colour is usually unaffected, and seldom higher than ordinary. If there is a very large proportion of mucus in the urine, a diffuse sediment of a viscid consistence, and of a white, yellowish, or dirty yellow colour, will separate itself.

If the urine exhibits a strong tendency to the formation of ammonia, the mucus will become very tough, and almost thready. The supernatant fluid is somewhat turbid, but heat induces no coagulation unless albumen be present.

The mucus may be recognised under the microscope by the peculiar mycus-granules, which are usually rather larger and less granular than those from the mucous membrane of the lungs or nose.

I have represented the mucus of the bladder, as it occurs in certain pathological states, in fig. 31 *a*.

Mucus frequently accompanies sediments of the urates and earthy phosphates, and its presence in these cases may be detected by the microscope. When mucus is separated in large quantity, (as in vesical catarrh,) carbonate of ammonia is soon formed, and we always find numerous crystals of ammoniaco-magnesian phosphate.

The quantitative estimation of the mucus must be effected in the manner described in page 396. The ratio of its weight to that of the solid constituents must be determined.

In order to ascertain the quantity of mucus in a sediment of urates and earthy phosphates, the sediment must be collected, the urates dissolved in hot water, and the earthy phosphates then taken up by acidulated water. The mucus will remain on the filter, and must be dried and weighed.

The method of conducting the quantitative analysis of diseased urine is precisely the same as for the healthy secretion, provided the changes are only dependent upon an increase or diminution of one or more of the normal constituents; indeed it may be still more simplified by omitting the exact determination of the lactic acid, the lactates, the chloride of ammonium, and the extractive matters.

The proportions of water and of solid residue must be determined, in the manner already described, from a weighed quantity of filtered urine. The residue, after being dried over sulphuric acid, must be moistened with a little warm water, and then thoroughly extracted with anhydrous alcohol. The undissolved portion must be dried, weighed, and incinerated. The extractive matters and uric acid are consumed, and there remain the earthy phosphates, the alkaline sulphates and phosphates, and the chloride of sodium, which must be separated and determined.

The anhydrous alcoholic solution must be gently evaporated, dried over sulphuric acid, weighed, and dissolved in a little water. The urea must be then precipitated as a nitrate, which must be separated and dried in the ordinary manner, weighed, and the weight of urea calculated from it. By subtracting the weight of urea from that of the whole of the alcohol-extract, we obtain as a residue the lactates, chloride of ammonium, alcohol-extract, and lactic acid, if any should be present.

The uric acid must be determined from a separate portion of urine. If any sediment occurs in the urine, it must be separated, and its weight ascertained in relation to the weight of the urine. After having ascertained its general nature, its various constituents must be determined by the methods already given.

If the morbid urine contains substances which do not occur in the healthy secretion, this method will even then often hold good, since the abnormal ingredients are sought for by independent processes. In many cases, however, a change is requisite; and I shall proceed to notice the various cases that may occur.

1. Qualitative and quantitative determination of substances which do not occur in normal urine.

Albumen is frequently present in the urine of persons suffering from disease, and indeed I once found it in the urine of a healthy vigorous young man, aged twenty-six years. If there is a considerable amount of albumen, nitric acid or bichloride of mercury will cause a precipitate, and the urine will become turbid on the application of heat, and deposit flocculi of coagulated albumen. Urine of this sort is usually pale and slightly turbid from containing mucus in suspension: its colours may, however, be high, as in the phlogoses; it may have an acid, neutral, or alkaline reaction, a high or a low specific gravity. When the quantity of albumen is very small, the application of heat is the most efficient test, and the most minute quantity of albumen may be readily detected by observing the uppermost part of the column of the fluid as it is being gently heated in a test-tube. When the temperature is sufficiently elevated, the coagulation begins to occur in the form of small white nebulae, which are dispersed by the rising of large bubbles, and the general turbidity of the whole fluid is often so slight that unless the development of these nebulae has been observed at the commencement of the process, it becomes a matter of difficulty to decide upon the presence of albumen. It is only in cases in which the urine has a decidedly alkaline reaction that nitric acid is preferable for the detection of small quantities of albumen, as in these instances the albumen is held in solution by the free alkali.

A turbidity may occur on the application of heat from the precipitation of earthy phosphates, or possibly of carbonate of lime, when no albumen is present; but in this case it is directly removed on the

addition of nitric acid: similarly, nitric acid may throw down a deposit of uric acid, which may be mistaken for albumen, but in this case no precipitate is caused by the application of heat. Dr. G. O. Rees has observed, that after the use of cubeb or balsam of copaiva, the urine is rendered turbid by nitric acid, although it contains no albumen; it is, however, not affected by heat. Hence, if there should be a tendency to the deposition of phosphates, a precipitate might ensue both on heating, and on the addition of nitric acid, and yet no albumen be present. I have confirmed the accuracy of the above observation; the precipitate consists of minute oil-vesicles readily soluble in alcohol, and possessing an odour of balsam of copaiva.

The quantitative analysis of albumen is best effected by boiling the urine, collecting the albumen on a filter, washing, drying, and weighing it, and ascertaining its weight in relation to that of the urine which was boiled, and to the solid residue. The portion of urine from which the albumen has been separated by boiling, may also be used for the determination of the other solid constituents and of the urea, if the quantity of albumen is not very large, and if the coagulated albumen is carefully washed. If the proportion of albumen is so large as to cause the urine to gelatinize on being heated, which, however, is very seldom the case, it may be feared that the coagulated albumen will entangle many other substances; in that case, the amount of solid constituents may be determined from a fresh quantity of urine, about 500—600 grains; the coagulated albumen must be treated several times with hot water before it is dried. When the quantity of albumen is very small, as for instance when the urine becomes only slightly turbid on heating, its amount cannot be determined with accuracy. It is then contained in the water-extract, and it is sufficient to state that the urine contains traces of albumen. If the amount of albumen is very considerable, certain changes must be made in the method of determining the other constituents. The albumen itself must be always separated by boiling.

In determining the urea we must see whether, when the albumen is very abundant, the greater quantity of it cannot be precipitated by alcohol. The albumen thus separated must be washed with alcohol. If we were to attempt to determine the urea in very albuminous urine in the manner described in page 397, there would be reason to apprehend that the albumen precipitated by the application of heat would entangle too large an amount of urea.

The determination of the uric acid is usually regarded as very uncertain in strongly albuminous urine. I have, however, convinced myself that this constituent may be separated from very albuminous urine by the careful addition of extremely diluted hydrochloric acid, [or acetic acid may be used, which precipitates uric acid without affecting the albumen.] It must also be observed that urine which is very rich in albumen always contains only mere traces of uric acid, and a very small proportion of urea.

In the determination of the water-extract, it must be borne in

mind that albumen is present in it. As its quantity is known, it must be subtracted from the combustible portion of the water-extract.

The spirit-extract is obtained from the portion of urine precipitated by alcohol, where it occurs in a state of solution. This solution must be filtered, evaporated, and all substances insoluble in anhydrous alcohol precipitated by the addition of that reagent. These are spirit-extract with chloride of sodium, and a certain quantity of albumen which remains insoluble on the addition of water. The watery solution of the spirit-extract and of the salts must be filtered, again evaporated, weighed, and then treated in the manner described in page 398.

If we wish to avail ourselves of the alcoholic solution which remains after the precipitation of the spirit-extract by anhydrous alcohol, for the estimation of urea, we must take another portion of urine for the determination of the alcohol-extract and ammonia-compounds, and proceed in the same manner as for the determination of the urea.

In the determination of the fixed salts it must be remembered that the earthy phosphates are increased by the phosphate of lime associated with the albumen, and as this generally amounts to 6 or 7 per cent., a corresponding amount must be deducted from the earthy phosphates. In other respects the method described in page 399 must be adopted.

[The following method for determining the amount of albumen has been recently proposed by Heller,¹ and offers several advantages.

A small quantity of the urine (from 20 to 10 grains) must be carefully weighed, and its solid residue accurately determined. In this way we estimate the per centage of solid residue. Another portion must be rapidly heated to incipient ebullition in a small narrow-mouthed flask. The mouth must be then closed, in order to prevent the escape of vapour, and the liquid when cold strained through a moderately fine linen cloth. The strained fluid is thus obtained perfectly clear, the albumen remaining on the linen as a snow-white magma. By treating a small quantity with nitric acid, we may be certain that the albumen is completely separated. The amount of the solid residue yielded by the strained fluid is determined, and the per centage calculated. The difference gives the per centage of albumen. If extreme accuracy is required, the flask with its contents may be weighed both before and after ebullition, and a correction made for the escaped vapour. In case the fluid should be alkaline, it must be previously acidulated with acetic acid.]

2. Constituents of the blood with the exception of fibrin.

Bloody urine is not of very unsrequent occurrence; it is distinguished by a more or less marked blood-red colour, sometimes being

¹ Archiv für phys. und patholog. Chemie und Mikroskopie, vol. 1, p. 192.

of a brown-red, and in other instances even of a brownish black tint. No remarkable series regarding the presence of blood can, however, be deduced from the colour alone. I have seen urine in colour ~~strongly resembling~~^{strongly resembling} bloody urine which contained not a trace of haemoglobin. Various resemblances to the colour of blood may be produced by mixtures of considerable quantities of haemoglobin, of urea-phosphoric acid, and of sulphuric acid. The presence or absence of the constituents of the blood may, however, be easily determined by the microscope, and by certain tests. If undissolved blood-corpuscles remain in the urine, as is frequently the case, they sink to the bottom and form a dark brown-red sediment in which their forms may be recognised by the microscope. The dark-red supernatant fluid coagulates on the application of heat in the same manner as ordinary albuminous urine; the coagulated matter, however, in this case is not white, but of a dirty brown colour. Similar appearances are produced by the addition of nitric acid. If the blood-corpuscles are perfectly dissolved in the urine, as I have sometimes observed to be the case, the microscope affords us no assistance. The application of heat, and the addition of nitric acid will, however, be sufficient to convince us directly of the presence of albumen and haemato-globulin.

The quantitative determination of blood in urine, and the changes which must be made, in consequence of the presence of a considerable quantity of that fluid, in the determination of the normal constituents are precisely similar to those already described in speaking of albuminous urine. It must be observed that the ash becomes reddened by the peroxide of iron which occurs in the haematin; and the fixed alkaline salts, as well as the earthy phosphates, are increased by the fixed salts of the blood, which usually amount to about 8 per cent.

3. *The constituents of the blood generally.*

Fibrin has been found associated with the other constituents of the blood which we have described as occasionally occurring in the urine.¹ Urine of this sort resembles blood in appearance; assumes, on being allowed to rest, a gelatinous consistence; trembles on the movement of the vessel; and, finally, separates into two portions, a clot, and thin fluid serum.

On examining, under the microscope, a little of the fluid obtained by pressing a portion of the clot, blood-corpuscles are observed: and upon kneading the clot in water we obtain fibrin, which may be washed perfectly pure. Under these circumstances there is no difficulty in ascertaining the presence of blood. If the blood has coagulated in the bladder, the urine will be of a blood or brown-red colour,

¹ [Fibrin has been detected occurring in a state of solution in urine, independently of the other constituents of the blood. Zimmerman describes seven cases of this nature, some of which are noticed at length in a future part of this chapter. (*Zur Analysis und Synthese der pseudoplastischen Prozesse*. Berlin, 1844, p. 129.)]

or even of a brownish-black, and will contain gelatinous flocculent coagula of fibrin, which, after remaining for some time in the urine may acquire a degree of transparency by the solution of their colouring matter.

It is only necessary, in these cases, to make sure that the coagula are not composed of mucus, a point which can be readily settled by the microscope, under which coagula of fibrin, upon compression between thin glass plates, present an amorphous granular appearance, while in the mucus-flocculi we recognise the well-known mucus-granules.

The quantitative determination of the constituents of the blood must be conducted in the manner described in 2. A method perfectly similar to the one which I have given for the analysis of blood may, however, be adopted, and in order to determine the urea in a certain quantity of bloody urine, the protein-compounds must be precipitated with alcohol, in the same manner as in albuminous urine.

4. Urine may contain fat either as an independent extraneous constituent, or associated with albumen, or with casein and the other constituents of milk. To distinguish these three morbid forms of urine we may term them, for brevity, *fatty urine*, *chylous urine* (Prout,) and *milky urine*. In addition to these forms, urine containing blood always contains, of course, a relatively corresponding quantity of fat.

Fatty urine. We occasionally observe that the urine of persons labouring under consumptive disorders becomes covered over with a glistening film. It would be precipitate to consider this, without further investigation, as a fatty coat, since I have observed a similar appearance on the surface of urine which had been standing for some time, and was just becoming ammoniacal. The microscope will immediately disclose the nature of the film: if it is composed of fat, we observe, on the microscopic examination of a small portion, an immense number of fat-globules; in the other case, we observe an amorphous granular matter. Cases have however occurred in which the urine has contained so large a quantity of fat that the oil-vesicles could be observed even with the naked eye, and formed a perfect stratum on the surface;—such cases have been recorded by Elliotson and Bachetoni.¹

The microscope is always sufficient for the recognition of fat in urine. If a quantitative determination of the fat is required, a weighed portion of urine must be evaporated and the residue repeatedly extracted with ether. The ether must then be evaporated, and the fat separated from the urea, and other constituents which may have been also taken up by means of water. This separation should be effected in a small porcelain basin, in which the fat must be heated till all aqueous moisture is dissipated, and then weighed. If the amount of solid residue is known either by this, or a separate expe-

¹ *Urinary Diseases and their Treatment.* By Robert Willis, M.D. p. 166.

riment, the proportion of fat to the urine, and to the solid residue, can be at once obtained. The residue, after the separation of the fat, will serve for the determination of other constituents, as urea or extractive matters; it must however be remembered that the water in which the fat was washed, contains some little urea.

Chylous urine. Chylous urine contains both fat and albumen; it is usually turbid, curdy, sometimes even resembling milk in point of colour. Under the microscope it exhibits numerous fat-vesicles. On the addition of a small quantity of acetic, or dilute sulphuric or hydrochloric acid, no coagulation occurs, even when gentle heat is applied; but on the addition of nitric acid a white precipitate is observed. Upon the application of heat to chylous urine, the albumen coagulates in flocculi. The methods of determining the amount of albumen and fat have been already given.

5. Casein.

Casein has never yet, so far as I know, been observed as a single extraneous constituent of the urine, as albumen sometimes seems to occur, but has always been found in combination with fat, and, in all probability, also with sugar, forming milky urine.

Milky urine is always turbid, of a yellowish-white colour, sometimes like milk, and when examined under the microscope, exhibits a quantity of fat-vesicles. Upon the application of heat to urine of this nature, coagulation will take place if a considerable amount of lactic acid is present, and then only a moderate temperature (86° to 104° F.) is sufficient. If it does not coagulate at this temperature, neither will it do so at the boiling point, as I have proved in an experimental mixture of milk with urine. If, however, albumen should also be present the urine will coagulate on being boiled. On the addition of a few drops of acetic, or dilute sulphuric or hydrochloric acid to a little of this urine, flocculi of coagulated casein will be formed if a moderate heat is applied. In order to determine the quantity of casein we must add a little acetic acid to a weighed portion of moderately warmed urine, and allow it to digest till the white flocculi of acetate of casein have separated themselves, and the urinary fluid has become clear.

The flocculi must be collected, washed, dried, and weighed. This is most readily effected on a light filter of known weight, which must be deducted, in order to give the true weight of the casein. The fat becomes entangled in the precipitated acetate of casein, and the filtered fluid exhibits only a few scattered fat-vesicles swimming in it. The fat may be separated, and its amount determined, either from the dried residue of the urine, or from the dried casein, by extraction with ether. The casein must be determined from a separate portion of urine; after this constituent has been separated the urine may be evaporated, and the urea and water-extract determined from the residue.

6. Brown pigment of the bile. (*Biliphæin.*)

It is no uncommon occurrence to find the urine tinged with this substance; in icterus it is always present. Urine of this sort is of a saffron, dark yellow, or yellowish-brown colour, and its sediment, if it contains one, is usually of a yellow or brown colour also. We cannot, however, always decide upon the presence of biliphæin from the colour of the urine, since haemaphæin, (the peculiar colouring matter of the urine) is capable of producing a similar tint. It is a peculiarity of urine coloured dark by biliphæin, that it exhibits in thin layers a characteristic saffron yellow colour. The presence of biliphæin may be at once detected with certainty by the addition of nitric acid, by which the well known transitions in colour, from green to violet, red, and yellow are produced. It is only when there is a considerable quantity of biliphæin present that these transitions can be distinctly observed, and the best method of proceeding is to pour a layer of urine carefully over nitric acid, and to continue the mixture of the two fluids gradually.

When the quantity of biliphæin is very small, the only changes that we are certain to observe on the addition of the nitric acid, are the transition of the yellow colour of the urine into green, which usually reverts to a yellow, without the intermediate colours being observed. Hydrochloric acid converts the yellow or brown colour of the urine into green, but does not develop the other tints.

An exact quantitative determination of the biliphæin in urine appears, with our present resources, hardly practicable, for its amount is usually very minute, and, like the animal colouring matters generally, it possesses the property of combining very intimately with other constituents. Thus we find uric acid, when it occurs as a sediment in icteric urine, mucus, the extractive matters, &c. always tinged yellow by biliphæin. We must therefore be content, in our estimation of the amount of the biliphæin, to draw our inferences from the intensity of the colour of the urine, and from the degree of change that it undergoes on the addition of nitric acid.

7. Bilin and bilifellinic acid.

The quantity of bile in urine is occasionally so large as to communicate to that fluid a decidedly bitter taste: in these cases biliphæin is always present. Whenever biliphæin occurs in urine, we are justified in suspecting the presence of bilin and bilifellinic acid, although they are not always found.

When the taste of the urine does not decidedly indicate the presence of bilin and of the acids of the bile, we must, in order to be assured of their existence, evaporate the urine, extract the residue with anhydrous alcohol, and then expel the alcohol by evaporation; the residue will contain bilin and bilifellinic acid, in addition to urea, alcoholic-extract, and the lactates; their presence may be recognised by the taste.

[The best method of ascertaining the presence of bilin (or choleic acid) is one recently published by Pettinkofer.¹ A small quantity of the urine or other fluid, supposed to contain bile, must be poured into the test-tube and treated with about two thirds of its volume of sulphuric acid, added by drops. Considerable heat is evolved, and the mixture must be kept below 144°, otherwise the bilin will be decomposed. A few drops of a solution of cane-sugar (five parts of water to one of sugar) are added, and the mixture shaken. If bilin be present, a violet red colour will appear, the distinctness of which will vary with the amount of bilin. The following precautions must be attended to:—1st, the temperature must not exceed 144°, otherwise the colour, although formed, will be again destroyed: 2dly, the quantity of sugar must not be too large, lest sulphurous acid should be formed, and the solution become of a dark brown colour: 3dly, the sulphuric acid must be free from sulphurous acid: 4thly, if albumen be present, it is advisable to coagulate and remove it before applying the test, since it gives origin (when present in a large quantity) to a tint somewhat resembling that produced by bilin: 5thly, a great excess of chlorides produces a brownish-red colour.

In liquids where the bile is in very small quantity, as in the urine and other secretions, it is often necessary to make a spirituous extract, to evaporate this nearly to dryness on the water-bath, and to transfer the moist residue into a watch-glass. When quite cold, sulphuric acid and a very small quantity of syrup are added, so that the temperature of the solution remains low. In the course of a few minutes, if the most minute trace of bile is present, the colour is produced. In employing this test, grape-sugar, or any substance convertible into grape-sugar, may be substituted for cane-sugar.

The nature of this reaction is unknown; it was at first considered that the peculiar violet tint might be dependent on the decomposition of the bile-pigment, but it was found to occur even in a more marked degree, with decolorized bile, and with pure bilin.

Another test has been recently proposed by Schwertfeger. He recommends that the urine should be treated with basic acetate of lead. When bile is present, the precipitate is yellow. On treating this precipitate with alcohol containing some sulphuric acid, we obtain a green solution, to which (as has been suggested by Dr. Griffith) Pettinkofer's test may be applied with advantage.]

For the purpose of forming a quantitative analysis of the bilin in the urine, we must evaporate a weighed portion, precipitate the water-extract and the salts insoluble in alcohol with spirit of 0·85, evaporate the spirituous solution, and extract the residue with anhydrous alcohol. The alcohol of this last solution is expelled, the residue dissolved in a little water, and some hydrochloric acid added; it is then allowed to digest till the resinous matter of the bile has separated itself, which must be washed, dried, and weighed. The presence of bile offers no

¹ Liebig's und Wöhler's Annalen, vol. 52, part 1.

impediment to the determination of the urea, for which purpose, however, a different portion must be used.

When icteric urine contains a sediment, it is usually of a yellow or brown colour, and in addition to the ordinary constituents of urinary deposits, it contains biliphaein. The sediment, in these cases, must be separated, and extracted with alcohol. This alcoholic solution must be united with the spirituous solution of the residue of the urine, from which the bilin was determined. The sediment must be analyzed according to the rules already laid down for the separation of uric acid, the urates, and earthy phosphates.

8. Sugar.

In diabetes mellitus the urine frequently contains a large quantity of grape or diabetic sugar, while the urea is at the same time either absolutely or relatively diminished. When the quantity of sugar is considerable, its presence can be detected without difficulty. The urine must be evaporated, and the syrupy residue treated with alcohol of 0·83. The alcoholic solution must then be evaporated till a yellow and very sweet syrup is left. Trommer, of Berlin, has discovered that the smallest quantity of grape-sugar may be detected in a fluid by the addition of a solution of sulphate of copper and of caustic potash.¹ On heating the mixture we do not obtain a black precipitate of oxide of copper, but the fluid becomes turbid, and a more or less considerable yellow, or yellowish-brown precipitate of reduced suboxide of copper is thrown down. According to the statements of Trommer, this method is particularly applicable to the detection of very minute quantities of diabetic sugar in urine; but since the ammonia-salts, the urea, and nitrogenous extractive matters, when heated with caustic potash, develop free ammonia, which impedes the action of the test, it is better to proceed in the following manner. The urine must be evaporated and the syrupy residue treated with anhydrous alcohol. Dry carbonate of potash must be added to this solution, and the mixture well shaken. The carbonate of potash dissolves and forms a layer beneath the alcohol. Upon the addition of some dissolved sulphate of copper, and the application of heat, there is produced in the lower portion of the fluid, a yellow or yellowish-brown turbidity, if sugar is present. Trommer states that this method is equally applicable for the detection of sugar in the blood.

The quantitative determination of sugar in urine is not very easy: I proceed in the following manner. A weighed quantity of urine is evaporated on the water-bath to the consistence of a thin syrup, and the residue treated with alcohol of 0·85, which precipitates the mucus, the salts insoluble in spirit, the water-extract, uric acid, &c. The spirituous solution is then evaporated to the consistence of a thick syrup, and anhydrous alcohol added, which precipitates the greater part of the sugar in the form of a yellowish-white

¹ See p. 65. Additional observations on the application of this test will be found in the remarks on the urine in diabetes.

magma. On pouring off the supernatant yellow alcohol, and repeatedly treating the magma with anhydrous alcohol, it gradually assumes a tough pasty form: it must then be warmed for some time on the water-bath, until all the alcohol is expelled, and be subsequently placed under a receiver over sulphuric acid, to dry. Ether is then added to the alcohol, in about the proportion of one volume of the former to two of the latter, by which an additional quantity of sugar is precipitated, whose weight must be determined separately. The substances now remaining in solution in the etherealized alcohol are urea and alcohol-extract. The fluid must be evaporated or distilled, and the urea determined from the residue by nitric acid. The sugar separated in this manner is not perfectly pure; it still contains chloride of sodium, extractive matters, and, in most cases, a small quantity of urea.

From the portion precipitated from the urine (after it has been reduced to a thin syrup) by alcohol of 0·85, and which consists of water-extract, earthy phosphates, uric acid, and mucus, the water-extract may be taken up by water, and determined after evaporation. The earthy phosphates may be taken up by water slightly acidulated with hydrochloric acid, from which they may be precipitated by ammonia: uric acid and a little mucus remain. The uric acid should be determined from a separate quantity of urine, according to the method described in page 397, for by this process we frequently obtain mere traces of it, and sometimes no indication whatever of its presence. The determination of the fixed salts in diabetic urine is of importance. Hunefeld has observed that diabetic urine frequently contains more chloride of sodium than the healthy fluid, a circumstance probably arising from the diet which is most commonly observed during the disease in question. In order to determine the fixed salts, a portion of urine must be evaporated, and the residue incinerated. The perfect incineration of the residue is a matter of some difficulty: it may be facilitated by moistening the carbonaceous residue with nitric acid, and then submitting it to red heat; or nitric acid may be added to the syrup at once, in which case a very large amount of carbon is burnt off immediately upon the residue being submitted to a red heat. The salts must be determined by the method described in page 399.

The exact determination of the solid residue of diabetic urine presents certain difficulties. A very small quantity of urine (from about 150 to 230 grains) should be evaporated in the water-bath, and the residue spread over the evaporating basin, which should then be placed under a receiver over sulphuric acid, for the perfect removal of the water. The quantities of sugar, urea, uric acid, &c. must be brought into relation with the amount of solid residue as well as with the whole quantity of urine.

Diabetic urine may also contain a tasteless species of sugar, which, according to Bouchardat,¹ corresponds exactly in its behaviour to-

¹ [Bouchardat now regards this tasteless sugar as a compound of the ordinary diabetic sugar with salts.]

wards yeast, and in its solubility in spirit, with sweet sugar, and may be separated in the same manner.

I have had one opportunity of examining diabetic urine, containing a slightly sweet sugar which was soluble in spirit, and also a considerable amount of insipid matter which was precipitated by alcohol, and appeared to resemble gum mixed with water-extract and mucus. I could not separate it from the water-extract, which is usually very scanty in diabetic urine.

9. *Carbonate of ammonia.*

In some diseases, especially in affections of the brain and nervous system, and of the bladder and kidneys, the urine possesses the property of becoming quickly alkaline; indeed I have observed instances in which it was alkaline at the period of its being passed. In these cases it has a very disagreeable, ammoniacal odour, and changes red litmus paper to a bright blue. In colour it may be either light or very dark; it ordinarily forms, in the course of a short time, a sediment of a grayish-white, and occasionally of a yellow or red colour, consisting of earthy phosphates. A certain test for the presence of carbonate of ammonia is afforded by holding a glass rod moistened in non-fuming hydrochloric acid over the urine; its existence is indicated by the formation of dense white vapours. On the addition of nitric acid to the filtered urine, numerous bubbles of carbonic acid gas are briskly developed. After a little practice the odour will be a sufficient indication of a very minute quantity of carbonate of ammonia. The quantitative analysis of this substance is seldom undertaken, but without doubt it is of importance, especially for the purpose of ascertaining whether an increase in the quantity of carbonate of ammonia necessarily involves a decrease in the amount of urea.

I have satisfied myself that in diseases of the spinal cord, when the urine often contains much carbonate of ammonia, it is formed at the expense of the urea. In four experiments, instituted with this object, I found scarcely a trace of urea in the urine.

An approximation to the amount of carbonate of ammonia may be made in the following manner. Dilute hydrochloric acid of known strength must be added *guttatim* to a weighed quantity of gently warmed urine, till, from being alkaline, the fluid becomes slightly acid. This point being attained, the warmth is continued for some time in order to make sure that the acid reaction is not due to the carbonic acid that has been liberated. The amount of carbonate of ammonia is then estimated from the quantity of hydrochloric acid which has been used.

10. *Oxalate of lime.*

Oxalate of lime not unfrequently gives rise to urinary calculi. A compound resisting a solvent power of the moderate acidity of the urine cannot, of course, occur in it in a state of solution: it has, how-

ever, been detected several times in urinary sediments, for which reason I refer to it here. Prout and H. Brett¹ have observed these sediments. The latter writer states that the urine was very high-coloured, and that the sediment was of a brownish tint. He ascertained its nature by its ready solubility in dilute nitric acid without any indication being afforded of the presence of uric acid, by its becoming white on incineration, by the ash then dissolving in hydrochloric acid with considerable effervescence, and by oxalate of ammonia producing an immediate precipitate, while no marked effects followed the addition of ammonia in excess: by these characters the oxalate of lime was thoroughly and satisfactorily made out. I once found oxalate of lime in the urine of a man with induration of the pancreas and suffering from great acidity of the stomach. The urine was neutral, or all but alkaline, and contained the minute prismatic crystals represented in fig. 36 d. They were insoluble in acetic, but dissolved in hydrochloric acid; and a further investigation left no doubt of their real nature. After some days the urine became remarkably acid, and deposited a sediment devoid of oxalate, but containing carbonate of lime.

[I have already mentioned that oxalate of lime is a much more common ingredient of urinary sediments than was formerly supposed. (See p. 79.) In order to detect it, place urine, passed a few hours after a full meal, in a large test-tube, and allow it to stand for some hours. Decant the upper 6-7ths, pour a portion of the remainder into a watch-glass, and gently warm it over a lamp; in a few seconds the heat will have dissolved any urate of ammonia that may be present, and will (by rendering the fluid specifically lighter) induce the deposition of crystals of oxalate of lime. Having allowed the urine to repose for a minute or two, remove the greater portion of the fluid with a pipette, and replace it by distilled water. A white powder, often of a glistening appearance, will now become visible, and this, under a microscope furnished with a half-inch object-glass, will be found to consist of crystals of oxalate of lime in beautifully-formed transparent octohedra, with sharply-defined edges and angles. (Fig. 36 a.) This process is the most satisfactory, and, after a little experience, can be performed in a few minutes. But even this may be avoided by placing a drop of the lowermost stratum of the urine on a plate of glass, placing over it a fragment of thin glass or mica, and then submitting it to the microscope; the crystals diffused through the fluid becoming very beautifully distinct. In this way, however, it is obvious that very much fewer are submitted to examination than by the former process. This salt never (or scarcely ever) subsides to form a distinct deposit; remaining for days diffused through the fluid, even when present in so large a quantity that each drop of the urine, when placed under the microscope, is found loaded with the crystals. A large quantity of the oxalate, when present, may escape the eye, in consequence of its refractive power approaching that of

¹ Urinary Diseases and their Treatment. By Robert Willis, M.D. p. 118.

the urine; for whenever we meet with a specimen in which the salt has partially subsided, and replace the decanted urine by distilled water, the crystals often become readily perceptible to the unaided eye, resembling so many glistening points in the fluid.

The crystals of the oxalate, when collected in a watch-glass in the manner above directed, are unaltered by boiling either in acetic acid or solution of potash. In nitric acid they readily dissolve without effervescing, and the act of solution can be observed with the microscope. When the oxalate is allowed to dry on a plate of glass, and then examined, each crystal resembles two concentric cubes with their angles and sides opposed; the inner transparent and the outer black, so that each resembles a translucent cube set in a black frame. (Fig. 36 b.) This is best observed under a half-inch object-glass; as with a higher power this appearance is lost.

In a very few cases the oxalate is met with in very remarkable crystals, shaped like dumb-bells, or rather like two kidneys with their concavities opposed, and sometimes so closely approximating as to appear circular, the surfaces being finely striated. (Fig. 36 c.)

The greatest possible variation in the size of these crystals is met with not only in different specimens of urine, but often in the very same portion. In a single drop of urine, octohedra of oxalate of lime may be frequently observed mixed with others four or six times their size. Dr. Golding Bird has given the following measurements of some of his preserved specimens:

	inch.
Length of a side of the largest octohedra	$\frac{7}{15}$
" smallest ditto	$\frac{3}{15}$
Long diameter of large "dumb-bell" crystals	$\frac{7}{13}$
Short diameter of ditto	$\frac{7}{15}$
Long diameter of the smallest "dumb-bells"	$\frac{1}{13}$
Short diameter of ditto	$\frac{1}{15}$

In the urine of the horse they are much larger, often being 1-150th of an inch long.

Many specimens of oxalic urine give a precipitate with salts of lime, insoluble in acetic acid, and consisting of oxalate of lime. This is often dependent on the presence of oxalate of ammonia, and delicate acicular crystals of this salt may be occasionally noticed, during spontaneous evaporation, on the border of the capsule.

Lehmann states that he has very frequently met with oxalate of lime in healthy urine, and that it often occurs in large quantity in cases of tuberculosis, arthritis, and especially of osteomalacia or softening of the bones. He has likewise met with it in endocarditis and other acute diseases. He states that the crystals are neither octohedra nor cubes, but four-sided double pyramids, which in their projection under the microscope appear as very minute cubes, or as somewhat larger octohedra. He further believes that a portion of the oxalate of lime is held in solution by lactic acid, and advises that if

the urine be very acid, it should be neutralized, boiled, and allowed to cool slowly, before looking for the crystals.

[For further information on this subject I must refer to the excellent little work by Dr. Golding Bird on 'Urinary Deposits,' from which the above observations are chiefly taken.]

11. *Carbonate of lime.*

[Carbonate of lime is a rare ingredient of urinary deposits. Dr. Griffith¹ describes it as consisting "of nuclei which were almost colourless, and studded with minute acicular crystals all over their surfaces."

It is occasionally met with in the alkaline urine common in cases of paraplegia following injury to the spine. In the majority of cases it forms an amorphous deposit mixed with prisms of ammoniacomagnesian phosphate. More rarely it is met with regularly crystallized, in compound spherical crystals, apparently built up of an infinite number of close-packed needles, radiating from a common centre. The outline of these masses is irregular, and their periphery is often apparently serrated. (Fig. 30**c.*) The carbonate of lime is normally present in the urine of many of the graminivora, especially of the horse. The dense deposit which forms in the urine of this animal consists of a mixture of carbonate and oxalate of lime. The former series form large spherical crystals like glass beads, which, when immersed in balsam, present the radiated acicular structure above described. (Fig. 30**a & b.*) Very beautiful evidence of structure is exhibited in these crystals of carbonate of lime, when examined by polarized light; a series of coloured rings traversed by a black cross being visible.]

12. *Cystin.*

[Cystin, when present in the urine, forms a nearly white or pale fawn-coloured pulverulent deposit, resembling the pale variety of urate of ammonia.² It appears to be merely diffused through the urine whilst in the bladder, as at the moment of emission the secretion is always turbid, and very soon deposits a copious sediment. On applying heat to the urine, the deposit undergoes no change, which serves to distinguish it from urate of ammonia; its insolubility in strong acetic acid prevents it from being mistaken for earthy phosphates. The best character of cystin is its ready solubility in ammonia, mere agitation of some of the deposit with liquor ammonia being sufficient to dissolve it, and a few drops of the solution evaporated on a slip of glass leaving six-sided tables of cystin. (See fig. 32 *a.*) A certain portion of cystin exists in a state of solution in the urine, as

¹ Med. Gaz., March, 1844.

² It is, however, always crystallized, a few regular six-sided laminae being often seen, but the great mass consisting of numerous superposed plates, so that the compound crystals thus produced appear multangular, as if sharply crenate at the margin, (fig. 32 *b.*) They thus resemble little white rosettes, when viewed by reflected light.

the addition of acetic acid always precipitates a small quantity. Urine containing cystin usually develops a peculiar odour resembling that of the sweet-brier, and often exhibits a peculiar greenish tint. (See Urinary Deposits, p. 379.)]

13. *Pus.*

Pus is not easily detected in the urine, especially when a small quantity is mixed with a much larger amount of mucus. I must refer to what has been already stated in page 370 regarding the distinctions between pus and mucus; it must at the same time be remembered that the mucus of the bladder differs in its properties from the bronchial mucus, and is less easily distinguished by the naked eye from pus. Urine containing pus may have an acid, neutral, or (and that not uncommonly) an alkaline reaction; at least it exhibits in most cases a strong tendency to the development of ammonia. The colour and amount of solid constituents are subject, according to Willis, to great variations. There is only one property of purulent urine that can be considered specific, and that is the invariable presence of albumen; too much stress must not, however, be laid upon this point, since urine is frequently albuminous without containing a single particle of pus, and we may very easily mistake albuminous urine containing mucus for purulent urine. In order to detect the presence of pus with the greatest degree of certainty, the urine should be analyzed as soon as it is discharged; it is then turbid, and very soon deposits a sediment, which, on the least motion of the glass, mixes with the fluid, and is again as quickly deposited. It forms a uniform substratum of a yellow, pale yellow-green, or yellowish-white colour, in which the presence of blood may also sometimes be recognised. On examining the sediment with the microscope, we find that it consists of pus-globules (fig. 17,) which, by inclining the stage of the microscope, may be readily caused to move; and if the colour should lead us to infer the presence of blood, the flattened blood-corpuscles may probably be observed. The pus-globules usually appear rather larger than the pus-globules of the lungs, and less granular; and I have observed that the nucleus can be more frequently recognised with clearness; the blood-corpuscles also appear tumid.

The filtered urine always contains albumen, sometimes in such quantity that flocculi separate on the application of heat. If the urine is allowed to stand for some time, and develops carbonate of ammonia, the pus becomes so viscid as to form a tenacious jelly. In these cases small quantities of albumen might escape notice on the application of heat, being held in solution by the carbonate of ammonia; to assure ourselves of the presence of albumen in these cases, we should make use of nitric acid.

In catarrhus vesicæ, in which a considerable quantity of mucus is frequently discharged, and where the urine is either thick and viscid at the time of emission, or very soon becomes so, a small quantity of pus may be easily overlooked.

URINE IN DISEASE.

On the general relations of the urine in disease.

Although I have, in the preceding pages, made many remarks on the general constitution of the urine in disease, I believe it will not be unacceptable to the practical physician if I offer some additional observations on the variations in the composition of this secretion, when it is pathologically changed.

The quantity of water in urine is always fluctuating, and may vary to a great extent; this point has been already referred to in our remarks on the physiology of the urine. The urine may exhibit remarkable differences in its external physical characters in persons suffering from the same disease,—a circumstance that analysis will enable us to trace to the different proportions of water that may be present. Frequent recourse to fluids, and the degree of activity of the process of transpiration must obviously have a very great influence on the amount of the watery portion, and therefore on the amount of the urine itself, and this is a point which the physician should never lose sight of in forming his opinion on the quantity of the discharged urine and on its degree of concentration. It is well known that the morning urine is more concentrated than that which is discharged during the day.

In consequence of the fluctuations, arising from various causes, in the amount of water in healthy urine, Becquerel¹ has come to the conclusion that its increase or diminution cannot be referred to the action of disease, except less than twenty-seven or more than fifty-two ounces are secreted in twenty-four hours, the average quantity in health being about forty-four ounces in that period.

The diseases in which the quantity of water separated by the kidneys is absolutely or relatively increased, are diabetes in its different forms, and certain hysterical or nervous disorders in which a perfectly limpid and thin urine is discharged in large quantity: thus Becquerel relates a case of a young chlorotic girl who ordinarily secreted daily about thirty-seven ounces of water by the kidneys, but in whom the amount rose to ninety ounces upon the accession of a severe hysterical attack.

The amount of water separated by the kidneys is diminished in inflammatory affections, in which Becquerel has seen it fall as low as twelve ounces in twenty-four hours. In these cases the urine is of a very dark colour, of a high specific gravity, and possesses a strong acid reaction. As the quantity of water increases, the solid constituents relatively, but not always absolutely, diminish, as may be found by comparing them with the amount secreted in twenty-four hours in a state of health.

The quantity of urea was found by Nysten to be increased in in-

¹ Sémiotique des Urines, &c. p. 19.

flammatory affections, and my own analyses of the urine during inflammation, on the whole, tend to confirm his statement; for I found it either absolutely or relatively increased, or equal to the quantity separated in a healthy state, or at any rate but slightly diminished. If we remember, however, that in these acute diseases only very small quantities of nitrogenous food are taken, and that the quantity of urea must naturally decrease under such a diet, we may regard it as increased even if it falls below the physiological average. Becquerel also found the amount of urea in acute diseases very little below the physiological mean.

The quantity of urea is diminished in diseases in which there is either an absolute deficiency of blood, or the blood is poor in corpuscles; thus Becquerel found the urine in chlorosis deficient in urea, and I have observed the same to be the case in the latter stages of typhus.

The relative proportion of uric acid varies much in different diseases. We may conclude from the observations which have been made that the amount is increased by disturbances in the circulating system, as in the paroxysms of fever, in inflammations, &c. The following pathological conditions lead, according to Becquerel, to an increased quantity of uric acid: fever; great general functional disturbances, such as arise from oppressive dyspnoea in pulmonary emphysema or cardiac disease, acute pain, convulsions, delirium, &c., especially when attended with fever; and diseases of the liver, as hepatitis, cancer, or cirrhosis. The amount of uric acid is diminished in those cases in which there is a deficiency of blood, or where the blood is poor in corpuscles. Becquerel found this to occur in cases of chlorosis and anaemia, and in persons in whom the vital juices seemed dried up. The amount of the salts in the urine fluctuates extremely during disease. Generally speaking, we may assume that the quantity of salts decreases in most pathological states of the system; the cases in which the salts increase during disease being very rare. Becquerel states that in those diseases in which the amount of urea is only slightly diminished, the proportion of salts is not materially affected; but that in those cases in which the urea suffers a considerable reduction, the same takes place with regard to the salts. Analyses of inflammatory urine are, however, opposed to this statement, since in these cases the urea sometimes exceeds the normal amount, while the salts are decreased in an extraordinary manner. It is to be regretted that Becquerel has not undertaken an exact quantitative separation of the different salts, as the increase or decrease of the fixed salts collectively is a circumstance of much less importance than the varying relative proportions of the individual compounds.

ON THE CONSTITUTION OF THE URINE IN DIFFERENT DISEASES.¹*Urine in the Phlogoses.*

In inflammatory affections, and in those diseases which are accompanied by that form of fever which is termed *sthenic* or *synochal*,

¹ Becquerel has attempted to classify every form of morbid urine under one of the four following heads: 1st, Febrile urine; 2d, Anemic urine; 3d, Alkaline urine; 4th, Urine differing but slightly from the normal standard.

1st. Febrile urine presents three distinct varieties:

a. Febrile urine, in the strict sense of the word, is passed by persons suffering from fever, or with severe functional disorders. This urine is characterized by a considerable diminution in the quantity of the water discharged by the kidneys in twenty-four hours, and by a slight diminution in the amount of the solid constituents, the urea and inorganic salts being below the daily healthy average, while the uric acid is increased. It is of higher specific gravity than normal urine, its colour is deeper and redder, it is frequently turbid, and often contains a small quantity of albumen. Becquerel gives the following analysis as a type of this form of urine: I place his analysis of healthy urine by its side, in order to render the differences in the two fluids the more striking:

Quantity of urine in twenty-four hours	True febrile urine. 23 ounces	Healthy urine (Becquerel). 45 ounces
Specific gravity	1021.8	1017.0
Water	964.0	972.0
Solid constituents	36.0	29.0
Urea	13.2	12.1
Uric acid	1.5	0.4
Other organic matters	14.7	8.6
Fixed salts	7.1	6.9

The urine is stated to assume the true febrile character in severe functional derangements, in chronic and acute inflammations, in general hyperasthenia, in diseases of the liver, the heart, and the lungs; in hemorrhages during their continuance, and in such organic degenerations of the different organs as result from fever or functional derangement.

β. Febrile urine, accompanied with great debility. In this variety of urine the water is likewise diminished. The specific gravity of the urine and the amount of solid constituents are considerably less than in the former case. With the exception of the uric acid, which remains normal, all the other constituents are absolutely, although not relatively, diminished.

The following analysis is given by Becquerel as a type of this variety of urine:

Quantity of urine in twenty-four hours	. . . . .	21 ounces
Specific gravity	. . . . .	1014.7
Water	. . . . .	974.0
Solid constituents	. . . . .	26.0
Urea	. . . . .	7.3
Uric acid	. . . . .	0.8
Other organic matters	. . . . .	10.5
Fixed salts	. . . . .	4.2

This form of urine is less concentrated than the normal secretion, is deeply coloured, and often turbid from the spontaneous deposition of uric acid. It occurs in those cases of fever in which there is great prostration and debility arising either from the disease itself or from very energetic treatment, such as free venesections or repeated purgations.

γ. Febrile urine in which the quantity of water is not affected. In this variety the daily amount of water is not less than in health; the urea and fixed salts are diminished; the uric acid and other organic matters are normal. The composition is illustrated by the following analysis:

Quantity of urine in twenty-four hours	. . . . .	45 ounces
Specific gravity	. . . . .	1010.5
Water	. . . . .	982.8
Solid constituents	. . . . .	17.2
Urea	. . . . .	6.8
Uric acid	. . . . .	0.3
Other organic matters	. . . . .	7.5
Fixed salts	. . . . .	2.6

the urine differs greatly in its properties from normal urine. In speaking of the probable cause of the changed constitution of the blood in the phlogoses, (see p. 233,) I showed that it is not to be referred to the diseased organ, but to the reaction which manifests itself throughout the vascular system. If the change in the constitution of the blood bears an accurate and inseparable relation to the fever, there can be no doubt that the change in the constitution of the urine must be in relation to the same cause, for the urine is separated from the blood, and was previously an integral constituent of it; and because, further, every alteration in the constitution of the blood must involve corresponding changes in the secretions and excretions, and more especially in the urine. Since like effects follow like causes, and since in inflammatory affections the vascular system similarly participates in the disturbance, we may assume *a priori* that similar changes will occur in the urine,—a point confirmed by experience.

The urine discharged during inflammations is usually termed febrile urine. There is no objection to this term, since the cause of the change in the urine must be sought for in the fever: I shall, however, not introduce the term 'febrile urine' here, since it is more than probable that the changes in the composition of the urine vary according as the character of the fever is synochal or torpid. My analyses show, in fact, that the relative proportions of urea in fevers of a torpid and of a synochal character are different; and although the analyses are not yet sufficiently numerous to establish the diffe-

The specific gravity is low, although the colour is usually deep. It does not deposit any sediment, and even after the addition of an acid, there is often no precipitation of uric acid.

2dly. Anæmic urine. This form of urine usually occurs in anæmia, chlorosis, &c. It is divided by Becquerel into the two following varieties:

a. True anæmic urine. The amount of water discharged by the kidneys in twenty-four hours is almost normal, while the solid constituents are considerably less than in healthy urine; the urea, uric acid, and fixed salts being much diminished, and the other organic matters decreased in a slighter degree. Its specific gravity is low, it is not deeply coloured, and it deposits no sediment. Its constitution is well represented in the following analysis:

Quantity of urine in twenty-four hours	.	.	.	.	.	38 ounces
Specific gravity	.	.	.	.	.	1010·3
Water	.	.	.	.	.	982·8
Solid constituents	.	.	.	.	.	17·2
Urea	.	.	.	.	.	6·51
Uric acid	.	.	.	.	.	0·25
Other organic matters	.	.	.	.	.	6·23
Fixed salts	.	.	.	.	.	4·20

b. Concentrated anæmic urine. In this form of urine the water discharged in twenty-four hours is much diminished, and the amount of solid constituents, although relatively increased, is absolutely diminished also. The urea, uric acid, and fixed salts are the most diminished; the other organic matters less so. This urine is of a green or livid tint, and is never red or yellow.

3dly. Alkaline urine. This variety is distinguished by its alkaline reaction on test-paper and by its ammoniacal odour. (When the urine has become alkaline by the use of bicarbonate of soda there is no ammoniacal odour developed.) It has been observed by Becquerel in acute and chronic nephritis, in diseases of the bladder accompanied with purulent secretion, in certain diseases of the brain, and sometimes in Bright's disease.

4thly. Urine not differing from the normal type occurs in slight non-febrile affections.

rence with certainty, it still appears to me to be a point of sufficient importance to demand attention, and one that should be carefully worked out.

In order to take a correct view of the composition of the urine, we must bear in mind the composition of the blood, the reaction of the vascular system, and the diet, since the mixture of the proximate constituents is dependent upon these circumstances.

The following are the general characteristics of the urine in inflammatory affections: The urine is darker than usual, and is of a yellow, brown, or reddish-brown tint; it has an acid reaction, and is generally of a high specific gravity. With respect to its most important constituents, the urea is either absolutely increased, or is at the ordinary physiological average, or may be a little below it; the uric acid is always absolutely increased, and so are the extractive matters, especially the alcohol-extract. The salts are always absolutely diminished, especially the chloride of sodium; the sulphates, on the other hand, either approximate to the physiological average, or are not far below it. Assuming, as the mean of numerous analyses, that the urea constitutes 39% of the solid residue of normal urine, I have found it as high as 46.8 in inflammatory affections. (In abdominal typhus, with a quick small pulse, I have seen it as low as 22.)

The physiological average of uric acid may be placed at 1.5% of the solid residue; in the phlogoses I have observed it amount to nearly 3%, and Becquerel even found it rise as high as 5.9%. The quantity of extractive matter, &c., which in normal urine amounts to 23.5% of the solid residue, rises in inflammations to 43%. The fixed salts, which, in healthy urine, constitute about 25% of the solid residue, diminish here to 12%. The sulphate of potash, which, in healthy urine, forms about 10% of the solid residue, I found to vary in inflammation between 7% and 9%.

The composition of the urine becomes changed if much blood is abstracted during the progress of the inflammation. It becomes clearer, specifically lighter, and the amount of urea decreases absolutely and relatively.

At the height of the inflammation, or (perhaps it would be better to say) at the time when the fever puts on the synochal type most strongly, the urine is usually clear and deeply coloured; it subsequently forms a sediment of a yellow or red colour, composed of uric acid and urates.

Pericarditis.

I have had an opportunity of examining the urine in pericarditis. A man aged 36 years entered the hospital with the symptoms of very acute pericarditis; the pulse was 108, very full and hard. The urine obtained for analysis was clear, of a deep fiery-red colour, had an acid reaction, a specific gravity of 1023.5, and, on being heated, gave indications of the presence of albumen.

The chemical analysis gave :

	Analysis 98.
Water	937-50
Solid residue	62-50
Urea	29-30
Uric acid	1-50
Extractive matters	22-70
Earthy phosphates	0-55
Sulphate of potash	4-89
Phosphate of soda	0-56
Chloride of sodium and carbonate of soda	1-40
	7-4

A strict antiphlogistic regimen with bloodletting was ordered. The blood taken at the first venesection exhibited, after coagulation, an inflammatory crust three fourths of an inch thick. At the fourth bleeding, when five pounds of blood had been abstracted, the inflammatory crust was one fourth of an inch thick, and the clot very firm. The urine now discharged (about thirty-six hours after the first bleeding) could hardly be considered darker than in health; it had an acid reaction, was devoid of albumen, and had a specific gravity of 1018. It was composed of the following constituents:

	Analysis 99.
Water	960-10
Solid residue	39-90
Urea	17-50
Uric acid	0-99
Extractive matters	15-10
Fixed salts	3-65

If we calculate the ratios of these constituents in relation to 100 parts of solid residue, and compare the numbers with the normal average, we shall detect in the first analysis the elements of a true inflammatory urine: the urea considerably exceeds the physiological average, the fixed salts collectively are diminished, while the sulphates are only a little below the normal standard, and the uric acid and extractive matters are increased. We see, at the same time, the effect produced upon the constitution of the urine by decided venesection.

100 parts of solid residue:

	In Analysis 98.	In Analysis 99.	In Normal Urine.
Urea	46-8	43-8	39-0
Uric acid	2-4	2-5	1-5
Extractive matters	36-2	37-8	23-5
Fixed salts	12-0	8-9	25-8
Sulphate of potash	7-8		10-3

[Zimmermann¹ found fibrin in the urine of a patient with "endocarditis of the right ventricle at the period of the commencement of hypertrophy." The urine was very variable in its characters, sometimes normal, sometimes sedimentary, and sometimes coagulable. In the latter case it was pale, and rapidly became alkaline.]

¹ Zur Analysis und Synthesis der pseudoplastischen Prozesse, p. 129.

Phlebitis uterina.

I have had several opportunities of examining the urine in phlebitis uterina. In one instance occurring in our hospital I found it of a dark colour, an acid reaction, and depositing a slight sediment of urate of ammonia and uric acid. In another case (that of a woman aged 30,) I likewise found it dark-coloured, but it had a slightly alkaline reaction with a disagreeable ammoniacal odour. It deposited a dirty yellow sediment, which appeared to the naked eye to be purulent, but which was shown by the microscope to consist of an immense number of mucus-granules, of a few crystals of ammoniacomagnesian phosphate, and of an amorphous precipitate of phosphate of lime and urate of ammonia. The clear urine developed some carbonic acid on the addition of nitric acid, and became turbid, from which the presence of albumen was inferred.

Meningitis.

In the acute form of meningitis the urine assumes the inflammatory type. Schönlein describes it as being of a dark red colour, very like brown beer. The secretion is usually scanty, (frequently only from eight to nine ounces in twenty-four hours,) it has a strong acid reaction, and the specific gravity and consequently the amount of solid residue is high. In four cases of meningitis observed by Becquerel, the mean specific gravity was 1025.2; sediments of uric acid sometimes occurred spontaneously, and were sometimes induced by the addition of nitric acid. In two of the cases he observed albumen. Schönlein observes that at the crisis towards recovery the urine is secreted more abundantly, and sometimes deposits purulent sediments.

Encephalitis.

The urine in encephalitis appears to be much the same as in meningitis. It sometimes deposits a sediment, and contains a small quantity of albumen. Becquerel found the specific gravity to be 1020.2.

[Considerable attention has recently been paid to the urine in the different forms of insanity. The most characteristic feature seems to be the excess of ammonia excreted as carbonate, urate, hydrochlorate, or ammoniacomagnesian phosphate. The reader may consult Erlenmeyer,¹ Heinrich,² and Sutherland and Rigby,³ on this subject.]

¹ *Observationes physiolog.-patholog. in morotrophicis Sigburgensi institut. de urina maniacorum.*

² *Ueber die Wichtigkeit mikroskopischer und chemischer Untersuchungen für die Psychiatrik, mit besonderer Rücksicht auf Harnsemitik.* (Häser's Archiv. vol. 7, 2.)

³ *Med. Gaz.*, June, 1845.

Delirium tremens.

In delirium tremens the urine is more or less of the inflammatory type; sometimes, however, it resembles normal urine in its colour and reaction. In a man aged 40, who had a very severe attack, Becquerel found the urine, acid for the first five days, with a mean specific gravity of 1017·2. It deposited a sediment either spontaneously or on the addition of nitric acid. In another man aged 40, who was also in the third stage of phthisis, and died three days afterwards, the urine possessed the characters of inflammation; it had a specific gravity of 1021·8, and deposited a sediment.

Myelitis.

In inflammation of the spinal cord the urine in many cases is much the same as in inflammation of the brain; it is red, acid, and sometimes thick and sedimentary. Becquerel, however, has observed cases of affections of the spinal cord in which the urine was not much removed from the normal type. In two persons aged 32 and 50 years respectively, who were suffering from a slight degree of paralysis of the lower extremities, the urine did not differ materially from the healthy secretion, although it varied on different days; it had an acid reaction, and contained a little more mucus than healthy urine.

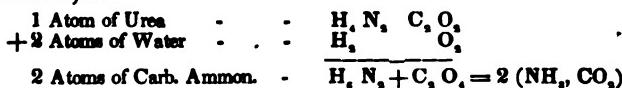
In inflammatory affections of the brain, and still more in those of the spinal cord, especially in chronic cases, the kidneys and bladder sympathize in a high degree: the latter is sometimes paralyzed. The character of the urine then changes in a very peculiar manner; it loses its acid reaction, and its colour becomes clearer: at the period of its excretion it is either slightly acid or neutral, and in a very short time it becomes alkaline, in consequence of the formation of carbonate of ammonia.

When first discharged, the urine is clear, generally of a bright yellow colour, and possesses rather an unpleasant odour. If allowed to stand, a glistening pellicle often forms very quickly on the surface, consisting partly of crystals of ammoniaco-magnesian phosphate, and partly of amorphous phosphate of lime, as may be seen by the microscope. The presence of ammonia may also be recognised at once by the odour, and by test-paper. After a time, the urine becomes turbid, and deposits a sediment of earthy phosphates and mucus, which sometimes assumes a purulent appearance, and becomes tough and viscid in proportion to the quantity of mucus which is present. The odour is then strongly ammoniacal, and often stinking and putrescent; and on the addition of hydrochloric acid to the urine, a well-marked effervescence is produced by the liberation of carbonic acid. Cases have however been observed in which the urine was ammoniacal at the period of its emission from the bladder. A man aged about 40 years was brought into our hospital with a severe cerebral affection; he soon sank into a state of deep coma, and the urine was emitted in-

voluntarily. On collecting the urine in a bottle, it had an unpleasant ammoniacal odour, an alkaline reaction, and soon deposited a sediment of mucus and earthy phosphates. Upon the addition of nitric acid after filtration, brisk effervescence took place, and the urine became turbid, in consequence of the presence of a slight quantity of albumen.

Becquerel observed much the same in four cases of chronic affection of the spinal cord, in which the functions of the bladder were impaired. The urine was discharged involuntarily, was of a dirty-yellow pale colour, of the ordinary specific gravity, and soon became alkaline; in those cases in which the urine was clearer, the specific gravity was lighter. The urine always contained a considerable quantity of mucus, muco-pus, or true pus, some albumen, ammonio-magnesian phosphate, phosphate of lime, and carbonate of lime.

In a former part of this work, attention has been directed to a peculiar arrangement which the elements of urea assume, when an aqueous solution of that substance is allowed to stand for a considerable period, or when it is treated with strong acids or alkalies. 1 atom of urea takes up 2 atoms of water, and becomes carbonate of ammonia, for



We have sufficient reason to justify the assumption that an arrangement of the elements of urea which occurs in pure water will also occur under certain circumstances in the kidneys or in the bladder, if the nervous activity, which has a very marked effect on the composition of the animal fluids, is changed, and if the urine contains mucus or muco-pus, which facilitate the new arrangement of the atoms in the same manner as yeast resolves sugar into alcohol and carbonic acid.

Inflammatory affections of the brain and spinal cord are not the only diseases in which carbonate of ammonia is formed in the urine: I shall subsequently show that alkaline urine is frequently observed in diseases of the kidneys and the bladder, and in nervous fevers.

In inflammation of the respiratory organs the urine generally exhibits the inflammatory type in a high degree, varying, however, with the development, extent, and intensity of the disease.

Bronchitis.

In bronchitis, if the attack is severe, and accompanied with much synochal fever, the urine is scanty, of a dark-red colour, strongly acid, and of a high specific gravity.

Becquerel observed an appreciable amount of albumen in the urine in such cases. The urine deposited a sediment, and had a mean

specific gravity of 1025·2. During convalescence, the urine either returns to the normal state, or assumes the anaemic type (of Becquerel,) i. e., it is pale, of low specific gravity, and deficient in solid constituents, especially in urea. In milder forms of acute bronchitis Becquerel found the urine highly coloured, sometimes sedimentary, and of a mean specific gravity of 1024·3. In the mildest forms, the urine scarcely deviates from the normal state.

Pneumonia.

In pneumonia the urine is subject to considerable variations dependent upon the extent of the disease, and the degree of inflammation. In severe inflammations, the urine is very dark, of high specific gravity, and frequently sedimentary, especially at critical periods and during the fever; Becquerel, however, once found that the urine deposited a sediment on the day when the fever ceased. An appreciable amount of albumen is by no means rare. The urine remains acid during the whole period of inflammation, and Becquerel found the same to be the case during the period of convalescence also. The mucus is increased during the febrile period, and this is observable in a more marked degree in women than in men.

Andral¹ has communicated some observations regarding the urinary sediments in pneumonia. Out of thirty-three cases, in twelve the urine remained perfectly clear throughout the whole course of the disease, and was not rendered turbid either by nitric acid or by heat: of these cases in six even the colour was not affected, and two sank under the disease. In nine of the thirty-three cases the urine was alternately clear and turbid, or sedimentary. The sediments were for the most part spontaneous, and composed of amorphous uric acid. In one of these nine cases the urine contained albumen. The sediments occurred, as might be expected, in the different cases, at different periods and under different modifications. In one the urine was clear and of a reddish-brown colour till the tenth day, and then formed for the first and only time a grayish-white precipitate. In another case the urine, which was of a brown-red colour, did not become turbid till the ninth day, when, as well as on the two following days, it formed a brick-red sediment. It then became clear, and remained so. In a third case, the urine, which was deep-coloured, deposited a grayish-red sediment on the seventh day, and then became clear and amber-coloured. In the other twelve cases that remain from the thirty-three, the urine was always turbid or sedimentary, either spontaneously or on the addition of a few drops of nitric acid, from the period of admission to the termination of the disease. Three of these twelve cases terminated fatally, and in these the urine remained turbid to the last. In the nine other cases the urine returned to its transparent state at the cessation of the disease.

¹ Becquerel, *Le Sémiotique des Urines*, p. 332.

Becquerel has arrived at the following results respecting the constitution of the urine in pneumonia.

In a case of acute pneumonia at the period of the crisis, the quantity of urine passed in twenty-four hours was 26 ounces, its specific gravity 1015·1, and its amount of solid residue 24·9 in 1000. The patient was depressed, his pulse 96, and the urine, as well as the skin, had a bilious tinge.

In a second case, in which there was intense fever, and the pulse was 120, 22 ounces of dark red urine of specific gravity 1021·8 were passed in twenty-four hours: there were 36 parts of solid residue in 1000 of urine. In a third case in which the patient had been much depressed by venesection and large doses of tartarized antimony, and where the pulse was 104, there were 30 ounces of dark-yellow, turbid, acid urine, of specific gravity 1015·9, and containing 26·3 of solid residue in 1000 parts, emitted in twenty-four hours.

Becquerel has made one complete analysis of the urine in a case of pneumonia in which the pulse was 100. He found

The quantity of urine in twenty-four hours					36 ounces
Specific gravity	-	-	-	-	1011·7
Water	-	-	-	-	980·6
Solid residue	-	-	-	-	19·4
Urea	-	-	-	-	7·3
Uric acid	-	-	-	-	0·4
Fixed salts	-	-	-	-	9·7
Extractive matters	-	-	-	-	8·6

I have made two analyses of urine passed in pneumonia. Analysis 100 represents the urine of a man aged 35 years; it was of a fiery-red colour, clear, and strongly acid; the pulse was full, 108 in the minute.

Analysis 101 represents the urine of a man aged 40 years; it was of a dark yellow colour, had an acid reaction, and contained a considerable quantity of mucus. In both cases there was a good deal of albumen.

	Analysis 100.	Analysis 101.
Specific gravity	1017·0	1020·0
Water	959·60	947·90
Solid residue	40·40	52·10
Urea	15·79	19·35
Uric acid	0·71	1·59
Alcohol-extract with lactic acid and ammonia-salts	9·34	9·65
Spirit-extract	1·10	3·18
Water-extract	5·84	6·40
Albumen	1·47	0·50
Earthy phosphates	0·42	0·56
Sulphate of potash	3·70	6·98
Phosphate of soda, chloride of sodium, and carbonate of soda	3·28	6·74

If we calculate the amount of the more important constituents in relation to 100 parts of solid residue in these three analyses, we shall find that they exhibit very close approximations to each other, and on contrasting them with the normal standard, it will appear that the urea is a little diminished, that the uric acid is increased, that the

salts are diminished, and that the extractive matters, especially the alcohol-extract, are increased in the urine of pneumonia.

	100 parts of solid residue of pneumonic urine contain: Bequerel.	100 parts of solid residue of normal urine contain: Simon.
Urea	37·6	39·0 37·2
Uric acid	20	17 26
Fixed salts	14·0	18·3 14·0
Extractive matters	45·4	40·0 37·0
Sulphate of potash	9·0	10·3

According to Schölein, the crisis in pneumonia shows itself in the urine by the secretion becoming turbid and sedimentary; after ten or twelve hours a crystalline micaceous deposit forms, above which the urine becomes clear.

The following instance is strongly confirmatory of Schölein's opinion. In a case of pneumonia that recently occurred in his own wards, the urine, during the height of the inflammatory stage, was dark, very acid, and deposited no sediment; at the period of resolution it became paler and neutral; one morning I found it yellow, neutral, and with a sediment of white crystals visible even to the naked eye. The microscope at once revealed the beautiful shapes assumed by the ammoniaco-magnesian phosphate. I was much struck with the singular relations of the urine itself. It was perfectly neutral; and any acid, even dilute acetic, threw down a white precipitate, which led to the supposition that caseous matter was present; I soon, however, found that this was not the case, for on treating a portion with hydrochloric acid and allowing it to stand for some time, very beautiful, nearly colourless crystals of uric acid were deposited.

Alcohol threw down a tolerably copious white precipitate, which was collected on a filter and washed with more alcohol. A portion of this precipitate was taken up by warm water, and left as a residue after evaporation; it was entirely consumed when heated on platinum foil: rubbed with caustic potash, it developed ammonia; warmed with nitric acid, it gave indications of the presence of a large amount of uric acid. The portion insoluble in warm water was readily soluble in hydrochloric acid, from which it could be again precipitated by ammonia, and on examining this precipitate under the microscope, I found that it was composed of ammoniaco-magnesian phosphate. Hence it follows that the white precipitate which I at first mistook for casein, consisted of uric acid combined with ammonia, which existed dissolved in the urine to an unprecedented amount.

[Heller¹ has recorded a singular case in which the urine emitted an odour of hydrosulphate of ammonia, and deposited a sediment of urate of soda, during this disease.]

The patient was a boy aged 14 years, with pneumonia of the right lung. The peculiar odour of the urine was first observed on the tenth day of the disease. The secretion on that day was copious, of

¹ Archiv für physiolog. und patholog. Chemie, vol. 1, 24.

a light-yellow colour, very turbid, and deposited an abundant clay-colour sediment. This sediment, when examined under the microscope, was found to consist of clear and beautifully defined large globules studded with numerous spines, mixed with smaller star-like objects of the same form. (See fig. 29 a.) There were also a few epithelium-scales and mucus corpuscles. The urine had a strongly alkaline reaction: its specific gravity was 1018.

Heller noticed the following reactions:

1. Acetate of lead produced at once a very dark brown colour, and, finally, a blackish-brown precipitate of sulphuret of lead.
2. Perchloride of iron (which seems to be the best test for sulphurated hydrogen in urine, since pure sulphuret of iron is thrown down, while the precipitate, caused by the former test, contains the chloride, &c.) rendered the secretion almost black.
3. Nitrate of silver showed that the chlorides were in great excess.
4. Nitrate of baryta indicated an abundance of sulphates.
5. Ammonia showed that the earthy phosphates were normal.
6. Nitric acid and heat indicated the existence of traces of albumen.

The urine contained in 1000 parts:

Water and hydrosulphate of ammonia	-	-	-	-	951.98
Solid constituents	-	-	-	-	48.03
Urea	-	-	-	-	13.21
Free uric acid	-	-	-	-	no trace
Albumen	-	-	-	-	traces
Urate of soda (in the sediment)	-	-	-	-	1.80
Extractive matters, with a large amount of hydrochlorate and carbonate of ammonia	-	-	-	-	27.40
Fixed salts	-	-	-	-	6.61

As the fixed salts contained a mere trace of chloride of sodium, and nitrate of silver added to the urine showed that the chlorides were in excess, it is clear that nearly all the chlorine must be referred to the hydrochlorate of ammonia. That the sediment consisted of urate of soda was proved chemically as well as microscopically. The uric acid was determined by the ordinary test; and the soda by incinerating a portion in a platinum spoon, dissolving the white residue in dilute sulphuric acid, evaporating, and obtaining crystals of sulphate of soda.

On the following day, (the eleventh,) the odour remained nearly unchanged, but acetate of lead and perchloride of iron showed that the amount of hydrochlorate of ammonia was diminished. There was a small flocculent sediment composed of urate of ammonia, mucus, and fragments of epithelium, but entirely free from urate of soda. The urine now contained a normal amount of uric acid, and about as much albumen as on the preceding day.

On the twelfth day the peculiar odour was very faint, and on the thirteenth it altogether vanished. The urine was still alkaline, but gradually resumed its normal characters.

There was nothing in the treatment to account for the production of the sulphuretted hydrogen, and it can hardly be ascribed to the decomposition of the small quantity of albumen in the urine.

Zimmermann once detected fibrin in the urine of a patient with pneumonia on the third day. The secretion was of a fiery red colour, but deposited no sediment.]

Pleuritis.

In pleuritis the urine comports itself much the same way as in pneumonia. It exhibits, especially at the height of the inflammation, all the signs of inflammatory urine, and sometimes contains albumen.

In order to form a correct opinion regarding the urine in this disease, it is of especial importance to pay attention to the various circumstances that may modify the nature of the secretion, as for instance whether the disease is simple or complicated, acute or chronic, whether there is much or little fever, to what extent the inflammation has proceeded, and whether there is any effusion. Becquerel observed several instances of pleuritis associated with pulmonary phthisis, and in fifteen out of seventeen cases observed by him, there was considerable effusion. In a man aged 36 years, with acute pleuritis, delirium, and certain typhoid symptoms, and whose pulse was 112 in the minute, the urine was of an orange-red colour, and on the addition of a drop of nitric acid, deposited a sediment of uric acid; it also contained a little albumen. The quantity of urine in twenty-four hours was 17 ounces, the specific gravity 1021, and in 1000 parts there were thirty-four of solid residue. In a man aged 23 years, who had sub-acute pleuritis, whose skin was slightly jaundiced, in whom there was slight anasarca of the lower extremities, (it being a case in which peritonitis was also suspected,) and who was much weakened by the free application of leeches, the urine was of a deep orange-colour and clear; on the addition of nitric acid it deposited an abundant sediment. In the course of twenty-four hours there were 26 ounces of urine passed, of specific gravity 1014·2.

1000 parts of urine contained:

Water	-	-	-	-	-	-	976·5
Solid residue	-	-	-	-	-	-	23·5
Urea	-	-	-	-	-	-	6·1
Uric acid	-	-	-	-	-	-	0·6
Fixed salts	-	-	-	-	-	-	6·4
Organic matters	-	-	-	-	-	-	10·2

Becquerel attributes the small amount of urea in this case to the debilitated state of the patient.

He found the mean specific gravity of the urine in seventeen cases of pleuritis to be 1021·8; in those cases in which there was a spontaneous sediment, it was 1024·8; and in those in which a sediment was produced by the addition of nitric acid, it was 1022·7. Albumen was present in three out of the seventeen cases. The amount of

THE SECRETIONS.

... is frequently increased, especially in the urine of women, but could never be detected.

Urine, which before the crisis is of a reddish colour, at that period deposits copious sediments.

[Zimmermann observed fibrin in the urine of a patient with pleuritis, from the third to the fifth day. The urine was of a dark yellow-colour, and very frothy.]

Pleuropneumonia.

I have had an opportunity of observing a case in which urine of a very peculiar nature was emitted during pleuropneumonia.

The urine of a man of about 30 years of age, who was recovering from an attack of pleuropneumonia, and whose renal secretion had always previously been rather dark-coloured, became lighter and neutral. It was found one morning of a citron colour, and had deposited a white crystalline sediment, which, when observed under the microscope, was found to consist of beautifully-formed crystals of ammoniac-magnesian phosphate, recognisable even by the naked eye, perfectly free from any mixture with phosphate of lime, urates, or mucus. The urine which was filtered off, had a slight alkaline reaction, but did not become turbid on heating: the addition, however, of any acid, even acetic, produced a copious white turbidity, which did not disappear on the addition of an excess of the acid, but slowly vanished on the application of heat. In the acid urine thus cleared by heat ferrocyanide of potassium produced no effect. On evaporating the urine a sediment was deposited, and on mixing the residue with alcohol, a large quantity of a white substance was precipitated, which did not dissolve in water, and consisted of phosphate of magnesia, urate of ammonia, and a little extractive matter. Since the precipitate induced by the addition of acids to the urine gradually crystallized, and exhibited all the properties of uric acid, it is clear that the turbidity and precipitate had been caused by the decomposition of a urate which must have been present in a state of solution, to a very large amount. The urine had a specific gravity of 1022.

1000 parts were composed of:

		Analysis 102.	In 100 parts of solid residue.
Water	-	951-10	
Solid constituents	-	48-90	
Urea	-	20-80	42-0
Uric acid ¹	-	1-48	3-0
Extractive matters	-	13-50	
Ammoniac-magnesian phosphate and other fixed salts	{	10-20	

The following day the properties of the urine were entirely

The colour certainly was the same, but it no longer had the reaction, nor did it form a crystalline sediment, nor was

¹ The uric acid existed in the urine as urate of ammonia.

any turbidity induced by the addition of an acid. Free ammonia alone produced a slight cloudiness.

In a case of peripneumonia that recently occurred in Schönlein's wards, the urine at the period of resolution exhibited precisely the same characters as in the above case, and as in the case of pneumonia noticed in page 459. There was a beautiful crystalline sediment of ammoniaco-magnesian phosphate, and any acid threw down a copious precipitate.

Cases such as these suggest two important questions, one of which may be readily answered by a series of careful observations: viz. whether these peculiar phenomena in the urine are connected with the process of resolution after inflammation of the respiratory organs?—and if so, what is the nature of the connexion?

The solution of the former question would afford material service in the prognosis of these affections. The phenomena persisted for three or four days, and in both cases recovery took place.

There was a man in Schönlein's wards with very extensive and intense peripneumonia, whose urine presented all the appearances of a saccharine fluid in which fermentation had been induced by yeast. It had a yellowish, turbid appearance, and its surface was covered by a thick layer of foam, in which numerous air-bubbles were developing themselves. Gas was likewise developed in the fluid itself, and in the amorphous yellow sediment that had been spontaneously deposited. The frothy covering and the sediment were composed of an amorphous matter, numerous crystals of an ammoniaco-magnesian phosphate, and mucus-corpuscles. On treating the sediment with a free acid, the crystals and a portion of the amorphous matter (consisting of phosphate of lime) were dissolved: the remainder was insoluble, and resembled coagulated albumen in its behaviour towards reagents. The urine contained no trace of sugar, but a considerable amount of carbonate of ammonia.

On evaporating some of the filtered urine to which hydrochloric acid had been added, there remained a large quantity of hydrochlorate of ammonia. Very little urea was present, the greater part having been converted into carbonate of ammonia through the influence of the protein-compound. Vesical mucus exerts a similar action, and consequently in catarrh of the bladder the urine rapidly gives off a very disagreeable odour, and the amount of urea diminishes in proportion as the carbonate of ammonia increases.

Martin Solon¹ states, that in twenty-four cases of pleuropneumonia, he found albumen in twenty-two; it was especially observed at the period of the crisis.

Empyema.

It was known to the ancient physicians that effusions of pus into

¹ Urinary Diseases and their Treatment. By Robert Willis, M.D. p. 157.

the thoracic cavity are, under certain circumstances and peculiar treatment, carried away by the kidneys.

Schönlein has observed several such instances, and I have had several opportunities, in the clinical wards of our hospital, of seeing cases of pleuritis with empyema, in which, after a proper course of treatment, turbid urine was discharged for some days. This urine contained albumen, and deposited a sediment, which, under the microscope and in its general physical relations resembled pus, or (in one case,) mucus mixed with pus.

The urine, which after some time became clear above the sediment, was of a dark colour, only slightly acid, and soon became alkaline. The symptoms of empyema gradually disappeared, in proportion as the urine continued to form purulent sediments.

Emphysema.

Becquerel has examined the urine in eight cases of pulmonary emphysema. When the emphysema produces violent dyspnœa, frequent cough and much general disturbance, the urine assumes the inflammatory type. Becquerel made one analysis of urine of this nature; it was of a dark brown colour, had an acid reaction, but deposited no sediment. Its specific gravity was 1016·8. It consisted of—

					In 100 parts of solid residue.
Water	-	-	-	972·3	
Solid residue	-	-	-	27·7	
Urea	-	-	-	13·0	47·0
Uric acid	-	-	-	0·4	1·4
Fixed salts	-	-	-	4·3	15·5
Organic matters	-	-	-	10·0	36·1

In a man aged 60 years, who had emphysema with bronchitis, the urine deposited a sediment, and had the high specific gravity of 1025·6. After he had taken purgatives for seven consecutive days, the urine became very aqueous and the specific gravity was only 1009·2. In two other cases in which emphysema was combined with cough and dyspnœa, the specific gravity was 1025·2 and 1022·2.

Angina tonsillaris.

In angina tonsillaris, when associated with synochal fever, the urine presents the inflammatory type. Becquerel observed a case in which the urine possessed the characteristics of inflammation in a high degree. It was red, and had the high specific gravity of 1029·7. In another case, which was combined with violent fever, the urine was dark-coloured, and had a specific gravity of 1023·9. In neither of these instances was there any sediment; but in the second case, on the seventeenth day, an abscess which had formed in one of the tonsils opened into the mouth, and on that day alone there was a spontaneous sediment of uric acid, and the specific gravity rose to 1025·2. In the three other cases, in which the fever was not so high, the specific gravity remained lower.

Gastritis.

Becquerel has made some observations on the urine during gastritis, especially the chronic form.

Of three cases, two got worse, and merged into the acute form. The other case was unaccompanied by fever, and the urine did not appear to differ materially from the normal type. Of the two cases, one was that of a woman who was free from fever at the period of her admission into the hospital. The urine was pale and the specific gravity low. Continued fever subsequently came on, and assumed a typhoid character. The urine immediately became denser, darker in colour, and turbid (*urina jumentosa*.) After some time the patient returned to her former state, and the urine again became clear. In the third case, that of a man aged 35 years, chronic gastritis suddenly merged into the subacute form; he had frequent bilious vomiting and fever. The urine retained the inflammatory type until the condition of the patient improved. In a case of very acute gastritis with green watery vomiting, I found the urine scanty, of an extremely dark-red colour, acid, and forming a dull yellow sediment of urate of ammonia and uric acid: in fact, exhibiting all the characteristics of the urine of inflammation.

Enteritis and Dysentery.

In a severe case of enteritis, with obstinate constipation, violent pain on pressure, green acid vomitings, and wiry pulse, only a small quantity of urine was excreted. It was of a fiery-red colour, acid, and, after some time, threw down a copious reddish sediment of uric acid and urate of ammonia.

Becquerel has observed the urine in enteritis and dysentery; when the diarrhoea is only trifling, and unaccompanied by fever, there is hardly any deviation in the urine from the normal state. If, however, severe diarrhoea and fever are present, the urine may assume the inflammatory type. In a case of simple enteritis with diarrhoea the urine was at first very turbid, of specific gravity 1023·1, and deposited a sediment of uric acid: it was afterwards normal, and finally became anaemic, the specific gravity falling to 1010·0. In another case it was invariably high-coloured and very concentrated, its specific gravity being 1024·3; in this instance there was a daily sediment.

In eight cases of mild enteritis and diarrhoea, Becquerel only on one occasion detected a small quantity of albumen.

In two cases of a more chronic form of diarrhoea in persons who had long suffered from disease and from insufficient food, the urine was very light-coloured, and of low specific gravity, 1011·7.

According to Schönlein, in purely inflammatory diarrhoea, the urine is of a fiery-red colour, causes scalding in the urethra, and forms, at the crisis, a crystalline sediment of uric acid.

In catarrhal diarrhoea, the urine is rather dark, and becomes more so in the evening: at the crisis, a mucous sediment is deposited.

In bilious dysentery the urine is of a dark-red colour, tending to a brown; during the crisis it yields a fawn-coloured precipitate.

Finally, in typhous dysentery, the urine is dark, turbid, and fetid. During the crisis it forms no precipitate, but becomes clear and loses its smell.

Hepatitis.

Very different opinions have been expressed regarding the constitution of the urine in hepatitis.

Rose¹ asserts that, in several cases of acute and chronic hepatitis, he found the urea entirely absent. In the acute forms the urine was dark, in the chronic it was clear. It possessed no urinous smell, and the specific gravity was lower than that of the healthy urine. Henry² found the urine, in a case of chronic inflammation of the liver, to be devoid of smell and colour, and of a specific gravity of only 1003. The extract obtained by evaporation gave no indications of urea on the addition of nitric acid. Rose puts the question, which can only be answered by farther analysis, whether the deficiency of urea arises from the actual inflammation of the liver, or from the dyspepsia that accompanies it. According to Coidet,³ the urine, in inflammation of the liver, instead of urea, contains a substance resembling bilin.

The analyses made by Becquerel and myself of the urine in hepatitis do not correspond with these statements. I analyzed the urine of a man aged 36 years, who was suffering from acute hepatitis. The urine was scanty, had an acid reaction, was of a dark reddish-brown colour, and deposited a copious red sediment of urate of ammonia and uric acid. On the addition of nitric acid the brown colour of the urine changed into a decided green. It likewise became turbid on the application of heat, so that it contained both biliphæin and a little albumen.

A quantitative analysis gave:

	Analysis 103.						
Water	-	-	-	-	-	-	939-70
Solid constituents	-	-	-	-	-	-	60-30
Urea	-	-	-	-	-	-	22-50
Uric acid	-	-	-	-	-	-	1-70
Alcohol-extract	-	-	-	-	-	-	9-70
Water-and spirit-extracts and albumen	-	-	-	-	-	-	6-30
Earthy phosphates	-	-	-	-	-	-	0-64
Sulphate of potash	-	-	-	-	-	-	5-30
Phosphate of soda	-	-	-	-	-	-	3-13
Chloride of sodium and carbonate of soda	-	-	-	-	-	-	9-50

The urate of ammonia was not estimated in that form, but was reduced to uric acid by the addition of hydrochloric acid, and

¹ Thomson's Annals of Philosophy, vol. 5, p. 423.

² Stark's Allg. Pathologie, p. 1152.

³ Ib. vol. 6, p. 392.

weighed as such. The carbonate of soda associated with the chloride of sodium, arose from the reduction of the lactates.

Becquerel analyzed the urine of a man (A) aged 33 years, who was attacked with icterus accompanied with fever and diarrhoea, after being in a violent rage. He was soon reduced to a state of great debility. The urine was very bilious, deposited a yellow sediment of uric acid, and had a specific gravity of 1013·0.

The urine of a woman (B) who had a chronic affection of the heart, and was attacked with acute hepatitis without very well-marked icterus, was of a deep yellow colour, but not tinged by bile. It deposited a spontaneous sediment, and had a specific gravity of 1018·9.

The composition of the urine in these two cases was as follows:

		A.	B.
Water	-	978·50	968·90
Solid constituents	-	21·50	31·10
Urea	-	6·15	13·10
Uric acid	-	1·14	1·57
Fixed salts	-	5·15	4·31
Organic matters	-	8·01	11·68

If we calculate the relative proportions of the various constituents in relation to one hundred parts of solid residue in these analyses, and compare them with the corresponding numbers in healthy urine, we find the proportions much the same as we have already found in pneumonia, except that in Becquerel's first case in which there was great debility accompanied with typhoid symptoms, the urea is very much diminished, whilst, in his second case, it is very much increased; in my case the salts were present to a large amount.

	100 parts of the solid residue of the urine in hepatitis contained		100 parts of the solid residue of healthy urine contained
	Becquerel.	Simon.	
1.	2.		
Urea	29·6	42·2	37·5
Uric acid	5·4	5·6	2·8
Fixed salts	24·0	13·9	31·3
Extractive matters, &c.	41·1	38·2	26·6
Sulphates			9·0
			10·3

Schönlein states that the urine in hepatitis is of a dark-red colour, approaching a brown, that it usually contains biliphaein, and that at the crisis a rose-coloured precipitate is formed.

[Herzog¹ has recorded the case of a woman aged 44 years, in whom the principal symptoms were pain in the left lobe of the liver, and vomiting. The urine was of a saffron colour, but contained none of the ingredients of the bile. Its specific gravity was 1035·7, and 1000 parts yielded 68·84 of solid residue, 55·15% of which were urea.]

Peritonitis.

I have had one opportunity of analyzing the urine in peritonitis puerperalis. It was passed by a woman aged 29 years, was of an

¹ Buchner's Report. 1844.

acid reaction, and somewhat turbid, but not particularly dark: when examined with the microscope, it was found to contain mucus-corpuscles, membranous shreds and other fragments, which could only be taken for epithelium composed of many regularly-formed, large, and elongated cells. On the application of heat the presence of a small quantity of albumen was detected. The specific gravity was 1020.0. The urine was composed of—

	Analysis 104.
Water	951.00
Solid constituents	48.20
Urea	20.10
Uric acid	0.83
Extractive matters	16.36
Fixed salts	9.20

By calculating the various constituents in relation to 100 parts of solid residue, we at once see that this urine is of a decidedly inflammatory type.

We obtain:

Urea	-	-	-	42.7
Uric acid	-	-	-	1.7
Fixed salts	-	-	-	19.1
Extractive matters	-	-	-	36.1

The urea even exceeds the physiological average, the salts are diminished, and the extractive matters increased.

[Scherer¹ analyzed the urine in three cases of febris puerperalis. The urine was usually of a fiery-red colour, sometimes neutral, and often alkaline (or at least it rapidly became so); it deposited a mixed sediment of pus, mucus, and urate of ammonia.

Two analyses gave the following results:

	1.	2.
Water	956.63	960.24
Solid residue	46.37	39.76
Urea	10.00	12.42
Urate of ammonia	2.04	0.84
Alcohol-extract	12.64	9.34
Water-extract	8.40	10.23
Soluble salts	6.69	6.34
Earthy phosphates	0.80	0.62
Albumen and mucus	2.60	Mucus alone 0.54

In the third case the urine resembled butter-milk, and was loaded with urate of ammonia; it contained:

Water	-	-	-	937.00
Solid residue	-	-	-	63.00
Urea	-	-	-	6.70
Urate of ammonia	-	-	-	3.20
Alcohol-extract	-	-	-	19.02
Water-extract	-	-	-	27.20
Salts	-	-	-	6.31

Bouchardat² has published an analysis of milky urine passed by a woman with this disease. It contained no traces of sugar or milk or casein, the appearance being due to a large amount of urate of am-

¹ Untersuchungen, &c. p. 72.

² Journ. de Connais. Méd. Août, 1843.

monia. It is moreover remarkable for the large quantity of fat and of albumen. It contained:

Water	.	.	.	.	.	940.9
Solid constituents	.	.	.	.	.	59.1
Urea	.	.	.	.	.	12.4
Uric acid	.	.	.	.	.	1.5
Albumen and mucus	.	.	.	.	.	29.2
Fat	.	.	.	.	.	2.5
Alcohol-extract with lactates, &c.	.	.	.	.	.	5.3
Alkaline sulphates	.	.	.	.	.	2.7
Phosphate of soda, and biphosphate of ammonia	.	.	.	.	.	4.2
Alkaline chlorides	.	.	.	.	.	0.8
Earthy phosphates	.	.	.	.	.	0.5

It must be observed that this urine was clear on emission, and only became turbid on cooling.]

Nysten¹ analyzed the urine of a person aged 23 years, suffering from peritonitis. He found it of a dark-red colour, perfectly transparent, of the ordinary odour of urine, and of an acid reaction. An albuminous pellicle formed on the surface during evaporation, and the whole finally coagulated into a trembling gelatinous mass. Nysten states that this urine contained thrice the quantity of urea that "urina sanguinis" contains. The numbers which he gives do not, however, make out so large a ratio. I calculate from the figures quoted in Meckel's Archiv,² that Nysten's "urina sanguinis" contains 40 parts of solid residue, of which 12 are urea, in 1000 of urine, whilst on the other hand, in 1000 parts of his inflammatory urine there are 76 of solid residue, of which 22 are urea. The urine in the latter case was evidently much more concentrated than in the former, but the ratio of the urea to 100 parts of solid residue is the same in both, and coincides with my own analysis and those of Becquerel. It amounted to 30 parts of urea in 100 of solid residue.

Nephritis.

In nephritis acuta the urine is, according to Schönlein, of a dark red or claret colour, and contains haematin; according to Rayer the secretion is very scanty, especially when both kidneys are diseased: it contains a certain quantity of blood or albumen, and has an acid, a neutral, or even an alkaline reaction; it occasionally contains pus, as when an abscess communicates with the pelvis of the kidney, or when the nephritis is accompanied by inflammation of the mucous membrane of the urinary passages.

Becquerel analyzed the urine in five cases of acute nephritis, and in none of them was blood present. The urine of a man who had acute nephritis possessed the properties of inflammatory urine, but contained neither pus, mucus, nor albumen, and deposited no sediment. In two cases accompanied with hectic fever, the urine assumed the inflammatory type, but contained no pus, and only, in one of the cases, a little albumen. In a woman who had, at the same time, dis-

¹ Recherches, &c. p. 240, 1811.

² Vol. 2, p. 648.

ease of the heart, chronic gastritis, and incipient cirrhosis of the liver, the urine was highly inflammatory; it was acid, formed a copious uric-acid sediment, and contained some mucus and albumen. In a woman aged 23 years, who had an anaemic appearance, and was suffering from slight polydipsia, and in whom the symptoms of acute nephritis showed themselves by violent pain in the right kidney, by continual vomiting for above ten days, by great anxiety and some fever, Becquerel observed that the urine remained quite unaffected: it was pale, clear, of low specific gravity, and very abundant. Willis directs attention to the sediment in simple nephritis, which distinguishes the disease from arthritic attacks; it usually consists of an amorphous powder of phosphate of lime with crystals of ammonico-magnesian phosphate, (if the urine is neutral or alkaline,) or of uratea. If any crystals of uric acid are present, they are only in small quantity. In speaking of the urinary crisis at the commencement of recovery, Schönlein observes that the urine is secreted copiously, and forms a creamy, and often a brown sediment, which afterwards separates itself into flocculent mucus; this mucous sediment will often go on for some weeks.

In nephritis arthritica the urine possesses very peculiar properties: Schönlein describes it as being of a fiery red colour, very acid, and soon after emission depositing glistening red crystals of uric acid. In one instance Schönlein found that the sediment occupied half the volume of the urine. Sometimes the sediment is of a yellow colour, and occasionally there is gravel, mixed with mucus and blood. According to Willis, the urine in arthritic nephritis contains crystals of uric acid, even at the moment of its emission.

If the disease terminates in convalescence, Schönlein observes, that either copious sediments of a sandy micaceous appearance present themselves, or gravel of varying size is discharged with the urine.

In nephritis albuminosa, or Bright's granular degeneration of the kidneys, the urine differs materially from the normal type in always containing albumen; in other points, as for instance colour and composition, it may also be changed, or may more or less resemble normal urine.

During the first stage of the disease, haematuria sometimes occurs; I have witnessed a case of this sort in our hospital, and have analyzed the urine, which was of a blood-red colour, and contained blood-corpuscles, but no fibrin. I subsequently analyzed the blood of this patient. (See Analysis 37, p. 263.) The urine was neutral, and when allowed to stand, formed a sediment which was shown by the microscope to consist of blood-corpuscles.

On the application of heat, there was a considerable coagulation of albumen, which was tinged brown by haematin.

The specific gravity was 1017·0.

The analysis gave:

	Analysis 105.
Water	948·14
Solid residue	51·88
Urea	7·63
Albumen	15·00
Globulin	1·00
Hæmatin, extractive matter with salts, and hæmato-globulin	23·80

I have in several cases made qualitative examinations of the urine in Bright's granular degeneration of the kidneys, and have always found it albuminous, usually pale, and of an acid or neutral reaction. The amount of albumen varies exceedingly.

Rayer,¹ who has long and accurately studied this disease, asserts, that, in the acute form of the disorder, the urine is at first discharged scantily, that it is coloured red or brown by the presence of blood, that it has an acid reaction, and has usually a higher specific gravity than normal urine; when allowed to stand, fibrous-looking red flocculi of blood, (fibrin?) are precipitated, which, when examined under the microscope, appear to consist of blood-corpuscles and mucus-granules mixed with epithelium. After some days the urine becomes of a citron-yellow colour, but upon the recurrence of the paroxysms the blood-red tint reappears, and disappears during the remissions. The amount of albumen discharged in twenty-four hours often fluctuates considerably. The amount of the other constituents, with the exception of the urea, does not seem to vary so much from the normal standard in the course of twenty-four hours in acute nephritis albuminosa as in the chronic form of the disease: the amount of urea is often only slightly decreased, and that of uric acid hardly at all, and consequently the specific gravity is not much affected.

In the chronic form of the disease, Rayer usually found the urine rather acid at the period of its discharge, but sometimes neutral or alkaline: it was always pale, often turbid, and at times had a curdy appearance from the presence of small white flocculi swimming in it, which, under the microscope, appeared as minute whitish lamellæ, (epithelium?) frequently mixed with an amorphous mucous substance. Sometimes the turbidity arose from the presence of fat.

Rayer states that the amount of albumen is larger in chronic than in acute albuminous nephritis, while, on the contrary, the amorphous urates and the phosphates are diminished in the former affection. In the chronic form of this renal affection, before the commencement of dropsy, the ratio of the quantity of urine to the drink which has been taken, hardly differs at all from the normal proportion. This state may continue for several months, during which period the presence of albumen affords us certain means of diagnosis.

Becquerel found the urine anæmic in the majority of his cases, (in sixteen out of twenty-two.) After the separation of the albumen, it appeared clear, pale, and of a greenish colour. Its specific gravity varied from 1006·3 to 1014·7. The mean specific gravity was 1011·3; sediments were not often observed, and the reaction was alkaline.

¹ Maladies des Reins.

The amount of urine differed very little from the normal quantity, and the relative proportions of the most important normal constituents to each other did not seem to be altered, but the urine was usually deficient in the amount of solid constituents.

In those cases in which Bright's disease was accompanied by other inflammatory attacks, by cardiac affections, by cirrhosis of the liver, or by pulmonary emphysema, Becquerel found the urine to possess the inflammatory type: it was of a dark colour, high specific gravity, an acid reaction, and not unfrequently deposited a sediment. Out of twenty-two cases of Bright's disease, Becquerel observed four in which the urine corresponded with the above description, and had a mean specific gravity of 1023.5. In two cases the urine was alkaline throughout the whole course of the disease, and deposited sediments composed of the phosphates of lime and magnesia, and carbonate of lime. The urine also contained in these cases a very large quantity of carbonic acid, which was combined with various bases (but chiefly with ammonia); the urea was at the same time considerably diminished, having yielded the elements for the formation of carbonate of ammonia. (See page 456.)

In some cases Becquerel found that the urine hardly differed at all in its physical characters from the normal type. He obtained the following results from seven analyses. They are calculated for 1000 parts:

	1.	2.	3.	4.	5.	6.	7.
Specific gravity	1016.3	1010.0	1007.5	1008.4	1005.4	1012.6	1010.0
Amount of urine in } 24 hours, in ounces }	28.0	35.2	62.0	78.0	106.0	25.3	
Water	965.0	981.5	987.5	986.3	980.1	975.5	981.5
Solid constituents	35.0	18.5	12.5	13.7	10.9	24.5	18.5
Urea	11.6	6.3	6.3	1.8	3.8	7.5	5.9
Uric acid	0.3	0.6	0.3	0.2	0.2	0.4	0.4
Albumen	11.9	2.5	0.1	3.4	2.6	5.9	
Fixed salts	6.6	4.1	2.5	2.9	1.7	4.9	3.7
Extractive matter	4.6	4.8	3.2	5.5	2.5	5.7	4.7

The urine in the 1st analysis was taken from a person suffering from Bright's disease without any complication. There was a little fever present. It was of a greenish yellow colour, very acid, and contained a little mucus. In the 2d analysis the urine belonged to a patient in whom the disease had assumed a chronic form; it was greenish, clear, and acid. In the 3d analysis the urine was taken from a person in a state of convalescence, and who afterwards recovered. The 4th analysis represents the urine of a man aged 35 years, who was suffering from polydipsia, with œdema of the feet, and ascites. The urine was clear, alkaline, formed a diffuse, whitish sediment, and effervesced briskly on the addition of acids. The man from whom the urine of analysis 5 was obtained, had tubercles in the lungs and Bright's disease in the first stage. There was infiltration of the feet, and slight ascites; the urine was acid, pale, clear, and very abundant. The urine in the 6th analysis was taken from a man who also had tubercles in the lungs and Bright's disease in the

first stage: there was no infiltration or dropsy: the urine was bloody and very acid.

If we compare these analyses of morbid urine with that of the healthy renal secretion, (the composition¹ of which is water 971·9, solid constituents 28·1, urea 12·1, uric acid 0·4, fixed salts 6·9, extractive matters 8·6,) we shall find that, with the exception of analysis 1, the solid constituents are less than in healthy urine, that the urea, with a single exception, only amounts to 1-3d or less of the solid constituents, whereas, according to Becquerel, it constitutes nearly one half in healthy urine, that the quantities of fixed salts, and also of extractive matters, are likewise less than in the normal secretion; that, on the other hand, the morbid urine contains albumen, which is altogether absent in a state of health.

My own analyses give a similar result, at least as far as the urea is concerned. I have recently analyzed the urine of a young man 21 years of age, suffering from Bright's disease, which was remarkable for the large quantity of albumen it contained. He had been attacked with anasarca and ascites, and the urinary secretion was diminished to about 12 ounces in twenty-four hours: the urine was of a dark-yellow colour, had an acid reaction, and formed a whitish mucous sediment, which, when examined under the microscope, appeared to consist, at least for the most part, of long, articulated tubes, similar to those of the conervæ, which were in part filled with a dark granular matter; there were, moreover, many globules filled with the same matter, which resembled Gluge's inflammatory globule; there were also mucus or pus-granules, and in one instance a slight quantity of very beautifully-crystallized yellow uric acid. I have since examined the sediment in various cases of this disease, and find that this appearance is by no means uncommon. To the naked eye sediments of this nature resemble a little mucus, but on carefully pouring off the urine and examining the deposit under the microscope we observe:

1st. Mucus-corpuscles of the ordinary size, more or less granular, and decidedly nucleated. Fig. 31, *a. a.*

2dly. Pavement epithelium, from the mucous membrane of the bladder. Fig. 31, *b. b.*

3dly. Blood-corpuscles. Fig. 31, *c. c.*

4thly. Round dark vesicles apparently filled with granular matter, and varying in diameter from ·0006 to ·0009 of a French inch. They strongly resemble Gluge's inflammatory globule. Fig. 31, *d. d.*

5thly. Tubes composed of an amorphous matter, resembling coagulated albumen. Fig. 31, *e. e.* That these tubes have in most cases an actual capsule and are cylindrical may be seen by inclining the stage, when they will rotate in the fluid in which they are floating. In some the capsule appears to be absent, and we can then see an amorphous, finely granular mass, adhering in a cylindrical form. Some of these tubes are full, others empty; the former contain a gra-

¹ It must be remembered that this is Becquerel's analysis of normal urine. See p. 404.

nular matter, darker at some points than others, and containing cells and vesicles, similar to mucus-corpuscles. The diameter of these tubes vary from .0011 to .0006 of a French inch.

I have satisfied myself, beyond a doubt, that they are derived from the epithelium investing the tubes of Bellini. Whether they are present as a consequence of Bright's disease, or whether they occur in other renal affections, must be decided by further observations: my present experience leads me to believe that they are cotemporaneous with a certain amount of albumen in the urine, but that blood-corpuscles need not necessarily be present with them. [These tubes occasionally present the twisted appearance represented in fig. 31, *f*, copied from Scherer. The diagnostic value of this form of sediment is uncertain; Schönlein regards it as an undoubted sign of Bright's disease; Scherer¹ has, however, observed it during the period of desquamation succeeding scarlatina; the same observation has been made by Lehmann, and I have myself observed it in various cases associated with a congested or irritated condition of the kidneys.]

On the fifth day from the commencement of treatment, the urine was much diminished in quantity; it amounted to only from 2 to 2½ ounces in twenty-four hours, was of a dark-brown colour, continued to exhibit an acid reaction, and deposited a very copious sediment in relation to the small quantity of fluid. The quantity of albumen was so great that perfect coagulation took place on boiling some of the urine in a test-tube; the tube could be inverted without any fluid escaping. On the seventh day the amount of urine increased, and it subsequently became still more abundant; its properties remained much the same till the eleventh day, after which the albumen decreased to such an extent that on boiling a portion of the urine, only about half its volume became coagulated. The first occasion on which the urine was analyzed, was when the secretion was reduced to a few ounces; the second occasion was on the day when it again became more abundant. In the latter case the solid constituents were much more abundant, although the urine was clearer, and as much as 12 ounces was passed in the twenty-four hours.

The following are the results of the quantitative analyses:

			Analysis 106.	Analysis 107.
Specific gravity	-	-	1014·0	1022·0
Water	-	-	966·10	933·50
Solid constituents	-	-	33·90	66·50
Urea	-	-	4·77	10·10
Uric acid	-	-	0·40	0·60
Fixed salts	-	-	8·04	10·00
Extractive matters	-	-	2·40	
Albumen	-	-	18·00	33·60

If we bring the quantities of urea and albumen in these analyses in relation to 100 parts of solid constituents, we shall see that in both cases they occur in nearly equal ratios: for in the first we have 14½ urea, and 54½ albumen; and in the second 15½ urea,

¹ Untersuchungen, &c., p. 57.

and 51% albumen. The amount of urea is very much diminished; if we brought it in relation with the solid constituents exclusive of the albumen, it would even then be below the normal average, and would amount to only 30%.

The observations of Bright, Christison, and others, on the properties of the urine in this disease, correspond in general with the account which we have given.

[Some excellent cases of Bright's disease with chemical examinations of the urine, are given in the work of Scherer, to which we have already referred.

Dr. Percy has published a case of Bright's disease, and given an analysis of the urine. Its specific gravity was 1020.

In 1000 parts there were contained:

Water	-	-	-	946.82
Solid constituents	-	-	-	53.18
Urea	-	-	-	7.68
Uric acid and indeterminate animal matter	-	-	-	17.52
Fixed soluble salts	-	-	-	5.20
Earthy phosphates	-	-	-	0.14
Albumen	-	-	-	22.64

Schlossberger has recently published a case in which, as the disease progressed, cerebral symptoms with maniacal paroxysms and perfect unconsciousness supervened, the paroxysms usually lasting for about twelve hours. The urine excreted before one of the paroxysms, and likewise that excreted during the first hour after the same paroxysm was submitted to analysis.

The urine, in both cases, was of a pale-yellow colour, faintly acid, somewhat turbid, and deposited a sediment of epithelium mixed with the tubes already described; in the course of eight hours there was also a considerable deposit of uric acid. The specific gravity of the former urine was 1011.6, and the secretion contained in 1000 parts:

		Before the paroxysm.	After the paroxysm.
Water	-	942.0	931.3
Solid residue	-	58.0	68.7
Urea	-	7.6	4.5
Uric acid with mucus	-	2.6	5.2
Alcohol-extract with salts	-	19.5	20.5
Water-extract with earthy phosphates	-	10.1	21.9
Albumen	-	17.9	17.0

In the second specimen there was a very large quantity of mucus.]

With respect to the analysis of very albuminous urine I must again refer to page 433, and I would expressly remark that the urine must be treated with absolute alcohol for the determination of the albumen and the urea, since we obtain inaccurate results in attempting to determine the urea from the evaporated solid residue. For the determination of the uric acid we must employ hydrochloric acid pretty freely diluted with water; it must be added carefully, in order not to precipitate any albumen. When blood occurs in the urine, we must adopt a precisely similar course.

Albuminous urine has now been so frequently observed in numerous diseased states of the organism independent of Bright's disease, that the idea has long been abandoned that granular degeneration of the kidneys always occurs when we have albuminous urine: the presence of albumen in the urine is, however, in no case a favourable symptom, and invariably indicates serious disease: I once, however, found a considerable quantity of albumen in the urine of a blooming and apparently quite healthy young man, and the only cause to which its presence could be assigned was that he had suffered from intermittent fever six years previously. There are various conditions under which this constituent may be present. During a catarrho-rheumatic affection I once observed a little albumen in my morning urine, but in the urine secreted in the middle of the same day not a trace could be detected. I noticed the following case of albuminuria in Schönlein's wards. A man suffering from pneumonia passed very turbid urine till the period of incipient resolution; it had a very acid reaction, and after several hours' rest deposited no sediment. The turbidity arose from urate of ammonia in suspension, it disappeared on the application of heat, and again became apparent as the urine cooled. The urine presented this jumentous appearance for six days; on the seventh there was a slight flocculent amorphous deposit of urate of ammonia. On gently warming the urine the sediment perfectly dissolved, but at a boiling heat it became turbid from the separation of a considerable amount of albumen. On the following day the urine was very turbid in consequence of the presence of urate of ammonia, the amount of albumen remaining much the same. From that date the urine became clear, but remained albuminous till convalescence was established, the albumen gradually disappearing as the health improved. During the whole of this period the patient complained of no pain in the region of the kidney, even on strong pressure; neither was there any deposition of mucus.

A man treated antiphlogistically for a severe attack of articular rheumatism passed, for a considerable time, urine of a dark colour and very acid reaction, which, however, threw down no sediment. During the period of convalescence, when the swelling and pain had diminished, the urine became less acid, without any appearance of a sediment; the sweat, however, was still extremely acid, and one morning the urine contained a very considerable amount of albumen.

This abnormal constituent occurred in the whole of the urine excreted that day; on the morrow it was nearly gone, and on the third day had quite disappeared. No renal irritation could be detected, neither was any sediment observed.

The urine of a young man with all the signs of general dropsy, contained a considerable amount of albumen, and deposited a light mucous sediment containing a considerable number of colourless blood-corpuscles (recognisable by their discoid form,) numerous exudation-globules, mucus-corpuscles, and a few of the tubes described in page 473. The urine had the pale, green, opalescent appearance

indicative of the presence of albumen, and did not contain a trace of haematin, which must consequently have been perfectly separated from the blood-corpuscles before leaving the kidneys. The patient complained of no pain (even on pressure) in the lumbar region.

I received a specimen of urine from Dr. Broun, which had been passed by a patient who for a long time had suffered from considerable oedematous infiltration of the extremities. It gave no indication of albumen, neither did it contain any of the peculiar sediment which seems especially associated with renal irritation.

That in certain forms of dropsy the urine is albuminous, while in others not a trace of albumen can be detected, has been thoroughly demonstrated. In hydrothorax, and in dropsy dependent on disease of the heart or the liver, there is generally no albumen, whereas, if the dropsy arise from disease of the kidney, albumen is generally present. In Bright's disease, as far as my personal observations extend, it is always found, although the opposite opinion is held by Graves.¹

Cystitis.

Two deviations from the normal condition are frequently observed in the urine in cases of cystitis; these are, its rapid tendency to alkalinity, in consequence of the formation of carbonate of ammonia, so that it is sometimes alkaline even at the period of emission; and the large amount of mucus or muco-pus. In the first stage of the disease the urine is, however, red, possesses all the characters of genuine inflammatory urine, and usually contains only a little mucus.

In cystitis acuta the urine was observed by Schönlein to be of a dark-red colour, and frequently to contain haemato-globulin. When the inflammation was caused by vesical calculi the urine had a pale greenish colour.

In a case of inflammation of the bladder, which was brought on by the use of stimulating injections, Becquerel found that the urine at first possessed the characters of the inflammatory type, but these in part disappeared in consequence of the quantity of the fluids drunk by the patient; it was acid, of average specific gravity, and deposited, after some time, a stratum of transparent mucus.

In another case in which the inflammation had been brought on in a similar way, the urine was alkaline, had a specific gravity of 1022·6, deposited a thick layer of purulent mucus, contained albumen and some fat which was removable by ether, and exhibited pus-corpuscles under the microscope.

In a third case of acute cystitis, which speedily came to a fatal termination, Becquerel found the urine, at the period of its discharge, turbid, thick, and viscid. On allowing it to stand for some time, there was formed a layer which occupied nearly the lower half of

¹ Dublin Journal, No. 60.

III METRITIS

In acute metritis the urine passes thin white pus; the fluid is thin, and consists of a dark green and white pus; the fluid above the sediment is transparent and the sediments are numerous. It is a sediment and often forms during the origin of the disease, it is now more abundant.

In chronic cases the sediment is composed of a granular or granitic appearance; it contains uric acid and in the latter case is a white mass also. Very rarely no uric sediment occurs, which are often tough and fibrous from the action of decomposers of bacteria. Sediments of this latter form frequently continue for a long time, so as to constitute granular albuminous residue. Sediment of urine, when it appears at convalescence the urine is of a dark reddish-brown colour, mixed with fibrous, granular, or bran-like mass.

Metritis.

In acute metritis the urine possesses all the characters of the inflammatory type. Bequerel found it acid, of a reddish colour, of average specific gravity 1016-0—1021-0, and sometimes containing albumen. A sediment of uric acid was always thrown down either spontaneously or by the addition of nitric acid; during convalescence it became paler and less dense, and ceased to deposit sediments. The leucorrhœa which accompanies metritis, or appears towards the period of convalescence, renders the urine turbid and cloudy.

In chronic metritis, and in uterine congestion the urine is much the same, except that the inflammatory signs are less marked. In these cases, especially in chronic metritis, it is frequently mixed with the leucorrhœal uterine discharge.

[In a case of endometritis¹ and pericarditis with purulent exudation occurring thirteen days after delivery, the urine was passed in very small quantity, evolved a disagreeable odour, was turbid, and deposited a rather copious sediment. The sediment consisted for the most part of pus, mixed with a few blood-corpuscles, epithelium-scales, and fat-vesicles.

The reaction of the urine was acid; its specific gravity 1020. It appeared on analysis that the urea was much diminished, that there were only traces of uric acid, that there was a little albumen, no bile-pigment; and scarcely any trace of chlorides. The sulphates were slightly, and the earthy-phosphates much increased.]

Urine in typhus.

We formerly had occasion to remark that less was known of the actual condition of the blood in typhus than in inflammatory diseases; the same observation is equally true with regard to the urine. Very

¹ Heller's Archiv, vol. I, p. 23.

little light has yet been thrown upon the varying nature of the urine in this disease: sometimes we find it of a brown colour, acid, and of high specific gravity, in fact, like inflammatory urine; sometimes it is clear like the urine after copious drinking; on other occasions it does not appear to differ from normal urine: it varies between an acid, an alkaline, and a neutral reaction. It is to be presumed that these changes in the relative constitution of the urine correspond with certain reactions in the organism; the connexion, however, is not always very clear, even to the observant physician. This much is, however, certain, that in the first stage of the disease a dark, specifically dense, acid urine is often excreted, and that in proportion as the fever assumes a torpid character, and the vital powers become depressed, the urine becomes clearer, loses its acidity, becomes neutral, and in a very short time (often after one to two hours) alkaline, containing carbonate of ammonia. Sometimes a yellowish-brown, turbid, fetid, and alkaline urine is excreted.

The difference between the urine in typhus and in inflammatory disorders is sufficiently great to be determined with certainty. In the phlogoses when the fever assumes a synochal character, we observe that the urine, with some few exceptions (as occasionally in cases of injury of the spinal cord, and in diseases of the kidneys and bladder,) is of a red colour, acid, usually clear, and only forms sediments of a yellow, red, or brown colour, and consisting of uric acid and the urates, on the occurrence of a crisis; the quantity of the urine is diminished, and the specific gravity increased; the urea is either absolutely increased, or is equal to, or very little below the physiological average; the quantity of salts is in general diminished, (the sulphates, however, in a much less proportion than the chlorides;) and the quantity of extractive matter increased.

In typhus the quantity of urine is decreased; it varies extremely, in colour and reaction; the red tint of inflammatory urine is, however, very seldom observed, but more commonly a brown or reddish-brown colour; the more the fever assumes the erythemic character, or approximates to the synochal form, in consequence of being complicated with inflammation of the respiratory organs, the more also does the urine approximate in its physical characters to the inflammatory type; and in proportion to the torpid character of the fever and to the prolapsus virium, does the urine become less dense and acid, and the more readily does it assume the alkaline state.

The urine may resemble the normal type as far as the specific gravity and the amount of solid constituents are concerned; it is usually, however, less dense, and it frequently happens that the deeply-coloured urine of typhus has a much lower specific gravity than we should have been led, from its tint, to expect. The amount of urea never reaches the physiological mean, and is often far below it; the uric acid, on the other hand, is often increased, especially on the occurrence of the urinary crisis. The salts, including the sulphates, are very much diminished, so that sometimes hardly a trace

the vessel, and consisted of almost pure and white pus: the fluid above the sediment was pale, clear, and alkaline.

As the disease terminates in convalescence copious sediments are deposited, or, if a sediment had been formed during the height of the disease, it is now more abundant.

In arthritic cases the sediment is, according to Schönlein, of a crystalline micaceous appearance; in non-arthritic cases (and in the latter stage, in arthritic cases also,) very bulky mucous sediments occur, which are often tough and fibrous, from the action of carbonate of ammonia. Sediments of this latter form frequently continue for a long time, so as to constitute genuine catarrhus vesicæ. Schönlein states, that in cystitis erysipelacea the urine is of a dark reddish-brown colour, mixed with fibrous, flocculent, or bran-like mucus.

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of them can be detected. We have seen that in the phlogoses the urea ordinarily attains the physiological average of $39\frac{1}{2}\%$ of the solid residue, and that it sometimes even exceeds it; while in the urine of typhus I found that the maximum proportion of urea amounted to only $31\cdot8\%$, the minimum to 22% , and the mean of 7 analyses to $26\cdot6\%$ of the solid residue. Hence it would appear that this decided decrease of the urea below the physiological average is a characteristic peculiarity of the urine in typhus. I found the maximum proportion of uric acid amount to $4\cdot8\%$, and the minimum to $0\cdot9\%$ of the solid residue; and with respect to the fixed salts, the maximum was 13% , and the minimum $3\cdot4\%$ of the solid residue.

With regard to the state of the urine in typhus, and especially in abdominal typhus, Schölein observes that it is altogether inconstant, that it is sometimes pale, sometimes apparently normal, and sometimes jumentous. In the first stage it is usually of a dark brownish-red colour, tolerably clear in the sthenic form of fever, but darker in the erythemic and very torpid forms.

A turbidity in the urine, together with other symptoms of a crisis, frequently indicates the transition into the second stage.

In this nervous stage of the disease the urine is of a dark brown colour, and very acid. A perturbation is observed in the urine on the seventeenth day, (occasionally it occurs on the eleventh or twelfth day,) and at the period of the actual crisis, (the fourteenth or twenty-first day,) the urine becomes clearer and more abundant; sediments also occur, not of a crystalline form, as in the phlogoses, but of a diffuse, flocculent, mucous nature: the urine sometimes becomes as clear as the *urina spastica*.

If the typhus disappears prematurely on the fourth or seventh day, we frequently observe, in addition to other acute critical symptoms, a discharge of turbid, and often purulent urine. In the form to which the term 'febris nervosa putrida' has been applied, when the decomposition of the blood is particularly striking, we meet with blood in the urine, which becomes very quickly decomposed, and is of a dark brown or blackish colour. Convalescence after typhus can never be considered as safely established until the urine becomes perfectly yellow and pale. As long as it remains of a dark brown, or even high colour, there is still danger. The more brown, decomposed, and fetid the urine is during the course of the typhus fever, the more unsavourable is the prognosis.

In petechial typhus during the first stage, the urine is not very highly coloured; on the seventh day there is frequently turbidity; during the nervous stage the urine is of a dark brown colour; and at the period of the crisis, sediments are also deposited.

Willis¹ remarks, that the state of the urine in typhoid fevers, especially in regard to its acid or alkaline reaction, may be studied with advantage, as affording an indication of the progress of the disease. During the early stage it is acid; as the disease advances it

¹ Urinary Diseases and their Treatment, p. 128.

becomes neutral, and then alkaline; as the disease decreases it again becomes neutral, and ultimately acid. The return to the acid state is always a good symptom, and will sometimes enable us to offer a favourable prognosis.

The observations made by Pelletan in Bouillaud's clinique, perfectly coincide with the above statements; he observes that, during the first days of typhus, the urine is of a dirty yellow colour, and transparent: during the whole of the first stage it is always more or less acid, and the darkest kind, which has an odour like gingerbread, is usually the most acid. At a later period it changes, resembles turbid whey or putrid broth, and is usually neutral; it is also sometimes found of a dark colour, with an odour like cow-dung. At a still later period, it is turbid, putrid, and smells rather ammoniacal, assuming at the same time a corresponding reaction. If the disease takes a favourable turn from this period, the urine goes through the same changes in a reversed order.

The observations which I have made in Schönlein's clinical ward correspond entirely with those already communicated.

In two men aged between 20 and 30 years, who had very severe attacks, I observed that the urine became alkaline towards the seventeenth and twenty-fourth days of the disease: it was then discharged in greater quantity than before, and was clearer; it was pale, somewhat turbid, and soon deposited a dirty or a bright-red sediment composed of earthy phosphates, urate of ammonia, and mucus. Test-paper and a rod moistened in hydrochloric acid, afforded indications of ammonia, and by the addition of an acid the presence of carbonic acid, but not of albumen, was demonstrated. Both men recovered, but convalescence, especially in one of them, was very slow. The urine then became gradually clear, yellow, and acid, as before: the period during which, in one of these cases, the urine continued uninterruptedly alkaline, was above eight days.

In another case, in which I followed the variations of the urine through the course of the disease, it became alkaline at noon on the third seventh-day period, but the next day it again became acid, and remained so till death, which soon occurred.

[Schönlein's opinion that the urine in the regular course of typhus is at first dark and very acid, subsequently neutral and even alkaline, and finally again becomes acid at the commencement of convalescence, has received further confirmation from the following observations quoted by Simon in his 'Beiträge.'

In one case the urine became faintly alkaline on the seventh day after admission; it remained either alkaline or neutral for seven or eight days; and then became faintly acid and gradually clearer, as soon as the patient exhibited symptoms of convalescence.

In a second (very severe) case the urine remained acid till the twenty-first day; it then became neutral, and afterwards alkaline, for the space of ten or eleven days, when it returned to its normal reaction.

In two other cases the urine became alkaline previously to the

fourteenth day of the disease; in one of them the secretion was so thoroughly saturated with carbonate of ammonia, and evolved so disgusting an odour as to be perceptible over the whole ward. This urine deposited a considerable sediment of pus or mucus, mixed with the phosphates of lime and magnesia, and effervesced briskly on the addition of an acid. In one of these cases the urine remained alkaline for fourteen, and in the other, for twenty-one days, before it resumed its acid reaction. Both cases recovered.

It is worthy of notice, that a deposition of urate of ammonia not unfrequently precedes the occurrence of alkalinity and the appearance of the earthy phosphates, which, as Schönlein remarks, may be regarded as the precursors of a favourable change.

During the mild form of typhus recently (1843) prevalent in Berlin, he noticed these changes in several cases, and in fact, when from being alkaline the urine again became acid, and at the same time clear and abundant, there was scarcely any risk in giving a favourable prognosis.]

In some cases in which the patients recovered, the dark urine did not become alkaline quickly enough to be perceived during the hospital-visit, but by the evening it would deposit a considerable dirty viscid sediment composed of earthy phosphates and mucus, and would have a well-marked alkaline reaction: subsequently it retained its acidity for a longer period, until at length it resumed its normal condition. On the other hand, I observed one case in which the urine was dark, had an acid reaction, and only became slightly alkaline for a short time before death; it continued throughout of this dark colour, was turbid, and threw down a mucous sediment. In another case the urine, which was of a dark, muddy colour, remained acid till death.

Lastly, I will refer to two cases of typhus in girls, where the urine continued of a dark colour, and exhibited an acid reaction, throughout the course of the disease, which lasted from three to four weeks. During convalescence it became turbid, and deposited an imperfect sediment: although it did not entirely lose its acid reaction, it now became sooner ammoniacal than before.

In a child the urine was clear and almost amber-coloured; it became, however, quickly alkaline, and deposited a viscid, white sediment of earthy phosphates. Dark acid urine I have frequently found to be slightly albuminous. From these observations, as well as from those of Willis, Pelletan, and others, we arrive at the conclusion that in a regular and favourable case of typhus the urine loses its acid and assumes an alkaline reaction; that it then again becomes gradually acid, although not perhaps in the exact reverse proportion, and that it does not necessarily reassume the dirty-brown colour which it possessed during the first period: consequently the transition of the urine in typhus from the acid to the alkaline condition need not be so much dreaded as has been generally supposed.

I cannot positively assert that the urine in typhus is alkaline at

the moment of its emission from the bladder. Becquerel expresses himself opposed to the idea; he considers that alkaline urine is only passed in those cases in which it has remained for a very long time in the bladder. I shall now give the facts which he has collected regarding the urine in typhoid fever. He observed the urine in thirty-eight cases of abdominal typhus, eleven of which were very severe, eighteen of ordinary intensity, and nine were mild cases. Purgatives, especially Seidlitz waters, formed the basis of the general treatment. Seven of the eleven severe cases recovered; two, however, subsequently died from tubercular phthisis. Of the four fatal cases, one died on the eighth day, the second at a more advanced period, the third on the fifty-third day, and the fourth from perforation of the intestines.

In all these cases Becquerel found the urine to deviate considerably from the normal type. While the fever was intense, and before the adynamic period was established, the urine was scanty, highly coloured, dense, and charged with uric acid; it sometimes contained blood, albumen, or mucus in considerable quantity, but seldom pus. In many cases, it exhibited a more marked tendency to decomposition than is observed in other diseases, and the rapidity and facility of this spontaneous decomposition usually corresponded with the severity of the disease. But when, in the progress of the disease, the adynamic period comes on, the quantity of the urine will be diminished in consequence of the intensity of the fever, the colour will be high, but the specific gravity low, and at the same time there will be frequent deposits of uric acid either spontaneous or after the addition of an acid, or else the urine will assume the anaemic type and be pale, of low specific gravity, and only slightly acid. The urine of this latter form differs widely from that which was passed at an earlier period of the disease, and is diagnostic of the asthenic state and of its degree of intensity. But exceptions to this general rule have been observed both by Becquerel and myself; on the one hand, the urine has been slightly coloured, clear, and of low specific gravity in cases of typhoid fever in which the patients were far removed from the asthenic state, and on the other hand the latter state (the asthenic) is not incompatible with turbid, sedimentary urine.

We must not overlook the circumstance of the urine having possibly remained for a long time in the bladder, in which case it may undergo decomposition there, and by its irritative action on the vesical mucous membrane produce an excessive secretion of mucus or even pus.

Becquerel found that the density of the urine, except in those cases in which there was great prostration of strength, was above that of normal urine, and amounted on an average to 1023.5. This, as I have already observed, is opposed to my own observations. The mean specific gravity of the urine which threw down a spontaneous sediment was, according to Becquerel, 1024.7. The colour of

the urine increased with the concentration. The colour of the spontaneous sediments in some cases resembled the brick-dust tint of the sedimentum latericum; the precipitates thrown down by acids were usually of a yellowish or gray colour.

In the thirty-eight cases of typhus observed by Becquerel, pus occurred in the urine of only one individual, and in this case the secretion was alkaline; in all the others it was acid. In a very extensive series of observations made by Andral the urine was found to have an acid reaction, except in the following cases, viz. when pus was present, when the urine had remained for a long time in the bladder, when the patient had taken a great quantity of alkaline fluids, or, lastly, when the secretion was not examined for some hours after its discharge.

The precipitate which Becquerel observed in the urine of typhus, whether thrown down spontaneously or after the addition of an acid, consisted of amorphous or crystalline uric acid; the latter was only seen twice, once after the addition of a little nitric acid, and in the other instance forming a portion of a spontaneous sediment. These spontaneous deposits were usually of a gray or reddish colour.

The important questions, whether urinary sediments in typhus occur at any fixed epochs of the disease?—whether there is any connexion between their appearance and a favourable result?—and whether their presence is prognostic of such a result?—are answered by Becquerel in the negative.

From a table communicated by Becquerel it appears that some persons died in whom the urine deposited a sediment either spontaneously or on the addition of an acid, almost uninterruptedly from the fifth or seventh day; while others, under similar circumstances, recovered: in a case, in which the urine threw down a sediment spontaneously on the third day of the fever, and after the addition of an acid on the eleventh, twelfth, and thirteenth days, death occurred on the fifteenth day; in other cases, in which sediments appeared at intervals, convalescence took place. Out of twenty-seven observations, a sediment first occurred in one case on the third day of the disease (death); in one case on the fifth day (death); in one on the sixth (recovery); in three on the seventh (two deaths, one recovery); in one on the eighth (recovery); in four on the ninth (recovery); in five on the tenth (recovery); in four on the eleventh (recovery); in three on the twelfth (recovery: in four cases the sediment first appeared after the twelfth day (recovery.)

Amongst Becquerel's thirty-eight cases, he only found blood in the urine in two cases: in one the patient was dangerously ill, and a small quantity of blood was found in the urine every morning; in the other, the patient was recovering from fever when he was attacked with small-pox. Albumen was found in eight cases, in which neither pus nor blood was present. Of these eight cases, four had the fever very severely, three moderately, and one slightly. Of the severe cases, two terminated in death; in one of these albumen was

only found during the last eight days; in the other it occurred first on the twenty-fourth or twenty-fifth day, and subsequently from the thirty-first to the thirty-eighth day, when death took place. In the other cases the albumen only appeared at intervals.

Andral examined the urine in forty-one cases of abdominal typhus, of which seven died. They were all treated by copious blood-letting. In eleven out of the thirty-four who recovered the urine did not differ in appearance from the normal type, and nitric acid threw down no precipitate. In the other twenty-three cases, the urine was generally deeply coloured, (of a reddish tinge,) and became turbid either spontaneously or after the addition of nitric acid. In some cases it remained turbid throughout the whole course of the disease; in others it presented no turbidity at first, even after the addition of nitric acid; but as the febrile symptoms attained their greatest height, it became clouded, and as they disappeared, it gradually regained its original appearance. In other cases the appearances of the urine possessed no regularity, and it was clear and turbid or sedimentary by turns.

The urine during the convalescence of the thirty-four cases, was usually pale and transparent; but in some it remained turbid or sedimentary for a considerable time after the termination of the fever. Albumen was only observed in one instance.

In these thirty-four cases the urine was acid during the whole course of the disease, and remained so during convalescence, except in two cases, in which it was invariably strongly alkaline, light, watery, pale, and transparent; the persons from whom the urine, in these cases, was derived, were very weak, and in a state of well-marked anaemia, having had the fever very severely, and having been repeatedly bled. The urine in these cases did not appear to have been retained in the bladder longer than usual. After several days, it became neutral; it then became gradually more deeply coloured, and ultimately regained its acid reaction.

With respect to the seven fatal cases, the urine in one retained its normal appearance; in four it assumed from the commencement till death a deep colour, and became turbid from an excess of uric acid which deposited itself; and in all the seven was invariably acid.

I shall now communicate the results of my own analyses of the urine in typhus, which enter more into minutiae.

I have made several analyses of the urine in abdominal typhus, but have only determined with accuracy the most important of the constituents.

The urine in analysis 108 was taken from a man aged 30 years, who had been dangerously ill for three weeks; delirium, subsultus tendinum, pulse frequent and small; the urine was moderately dark, turbid without a sediment, and strongly acid. He died two days afterwards. It is worthy of remark that the urine had on one occasion, about eight days before death, an alkaline reaction; it returned to its acid condition the following day. Analysis 109 represents the

urine of a typhus patient, who was lying in a state of deep coma; it was pale, and had an acid reaction. Analysis 110 represents the urine of the same patient three days afterwards, when he was in a state of great general debility; it was pale, transparent, and slightly acid, but after some time became alkaline, and deposited a sediment of earthy phosphates. The patient subsequently recovered after a tedious convalescence. Analysis 111 represents the urine of a typhus patient on the eighteenth day of the disease; it was dark, tolerably clear, threw down no sediment, and had an acid reaction. The urine in analysis 112 belonged to a person who had been suffering from typhus for some weeks; delirium, subsultus tendinum, stupor, rapid and very small pulse; it was brown, turbid, of an unpleasant odour (like the urine of horses,) slightly alkaline, and deposited in a short time a very copious, flocculent, reddish sediment of ureate of ammonia. Analysis 113 represents the urine of a girl suffering severely from typhus, who lay in a state of great prostration and coma, and afterwards died; it was of a dark-brown colour, slightly alkaline, rather turbid, and without a sediment; a deposit of earthy phosphates was, however, subsequently formed. Analysis 114 represents the urine of a girl who had had typhus for four weeks; coma, subsultus tendinum, pulse 120 and small. It was rather dark, was turbid, and had an alkaline reaction and ammoniacal odour. The urine in analysis 115 was taken from the same girl two days afterwards: her general condition much as before, pulse 112, urine neutral, of a yellowish-brown colour and rather turbid. Analysis 116 represents the urine of a girl aged 20 years, in whom the fever was less severe than in the previous case: there were symptoms of bronchitis, pulse as high as 108, urine of a yellowish-brown colour, and slightly acid. The urine in analysis 117 was passed by a man aged 30 years, who had been ill fourteen days. Coma; pulse 108, and small.

		Anal. 108.	Anal. 109.	Anal. 110.	Anal. 111.	Anal. 112.
Specific gravity	-	1016-00	1010-00	1009-00	1017-00	1016-00
Water	-	960-00	971-00	975-00	960-00	963-50
Solid constituents	-	40-00	29-00	25-00	50-00	46-50
Urea	-	9-47	7-30	6-70	—	10-50
Uric acid	-	1-10	0-62	0-40	—	1-50
Earthy phosphates	-	—	trace	trace	—	trace
Sulphate of potash	-	—	trace	trace	—	—
Sum of fixed salts	-	2-50	1-00	1-00	6-50	5-20
		Anal. 113.	Anal. 114.	Anal. 115.	Anal. 116.	Anal. 117.
Specific gravity	-	1015-00	1016-00	1013-50	1018-00	1018-00
Water	-	958-40	952-60	950-80	941-50	930-00
Solid constituents	-	41-60	47-20	43-20	58-50	70-00
Urea	-	9-30	13-20	12-60	10-60	22-50
Uric acid	-	0-40	1-60	2-10	0-92	1-47
Earthy phosphates	-	—	—	trace	—	0-90
Sulphate of potash	-	—	—	0-64	—	—
Sum of fixed salts	-	—	—	2-76	2-80	2-90

If we calculate the ratios of these constituents to 100 parts of solid residue, and compare them with the average ratios in normal urine,

all arrive at the results noticed in page 480, viz. that in the typhus the urea falls below the physiological average, the acid is increased, and the fixed salts are much diminished.

100 parts of the solid residue of the urine in typhus, there are contained:

100 parts of the solid residue of normal urine contain

Analyses											
108.	109.	110.	112.	113.	114.	115.	116.	117.			
23.6	25.0	26.8	22.6	22.0	28.7	31.2	31.8	32.3			39.0
{ 27	{ 21	1.6	3.2	0.9	3.2	4.8	1.6	2.1			1.5
{ 60	{ 34	4.0	11.1	—	—	6.3	4.8	4.1			25.8

Scherer¹ has made several analyses of the urine in typhus, which in some points from those of Simon. He observes that, in cases, the urine is tolerably abundant in lactic acid and excreted matters, and continues so throughout the case, whether it ate fatally or not. In a few cases the urine was alkaline, and generally occurred when the fever assumed a very low or putrid form; or when the contents of the bladder had not been discharged for some time; and that not unfrequently, after being acid, it became alkaline, and then again acid. In the most severe cases it usually contains a little albumen.

urea was never increased except in those cases in which the acid was much diminished, and was often much below the standard. As a general rule, the fixed salts were considerably diminished, and the ammonia-salts increased. There was an excess of uric acid, which usually separated, after standing, in the form of small red crystals, on the sides of the vessel; this was usually observed when there was much pulmonary congestion. These typical phenomena indicated the commencement of convalescence.

Scherer has published the following analyses:

In a woman aged 38 years, with slow nervous fever. The urine on the ninth day contained, in 1000 parts:—

Water	-	-	-	-	-	945.48
Solid constituents	-	-	-	-	-	54.52
Urea	-	-	-	-	-	8.60
Uric acid	-	-	-	-	-	0.60
Alcohol-extract with lactic acid and lactates	-	-	-	-	-	27.50
Water-extract	-	-	-	-	-	7.40
Albumen	-	-	-	-	-	1.80
Fixed salts soluble in water	-	-	-	-	-	6.20
Earthy phosphates	-	-	-	-	-	2.30

On the 12th day of the disease it contained:

Water	-	-	-	-	-	951.26
Solid constituents	-	-	-	-	-	48.74
Urea	-	-	-	-	-	10.40
Uric acid	-	-	-	-	-	0.70
Alcohol-extract with lactic acid and lactates	-	-	-	-	-	21.80
Water-extract with ammonia-salts	-	-	-	-	-	7.90
Albumen	-	-	-	-	-	1.00
Fixed salts soluble in water	-	-	-	-	-	5.30
Earthy phosphates	-	-	-	-	-	1.20

¹ Untersuchungen, &c. p. 65.

On the 15th day it contained:

Water	-	-	-	-	959.29
Solid constituents	-	-	-	-	40.71
Urea	-	-	-	-	11.40
Uric acid	-	-	-	-	0.80
Alcohol-extract with lactic acid and lactates	-	-	-	-	15.70
Water-extract	-	-	-	-	6.20
Albumen and mucus	-	-	-	-	0.90
Fixed salts soluble in water	-	-	-	-	4.50
Earthy phosphates	-	-	-	-	0.60

Convalescence occurred very slowly, without any critical phenomena. The urea gradually increased and the extractive matters diminished.

2. A man aged 66 years, of a muscular frame and good constitution, but of intemperate habits. The disease developed itself with great rapidity. The urine contained:

		On the 4th day.	On the 6th day.
Water	-	939.30	934.60
Solid constituents	-	60.70	65.40
Urea	-	23.84	34.52
Uric acid	-	1.70	1.62
Alcohol-extract with lactic acid and lactates	-	20.73	20.20
Water-extract	-	7.20	8.61
Fixed salts soluble in water	-	4.02	—
Earthy phosphates	-	0.72	1.02

3. In a case of typhoid fever of a very putrid character, the urine was of a red colour and an acid reaction. It contained in 1000 parts:

		1.	2.
Water	-	983.5	965.3
Solid constituents	-	165	347
Urea	-	12	53
Uric acid	-	0.5	1.5
Alcohol-extract, with lactic acid and lactates	-	65	15.8
Water-extract and ammonia-salts	-	62	6.9
Fixed salts soluble in water	-	18	3.6
Earthy phosphates	-	0.2	0.4
Albumen and mucus	-	0.5	0.7

The specific gravity in these cases was 1007 and 1011. Analysis 2 was made after the patient had taken phosphoric acid for some days, and the septic tendency had diminished.

Urine in intermittent fevers.

The urine varies considerably in its physico-chemical relations in this class of fevers. An abundant lateritious sediment at the period of the crisis was formerly regarded as an acknowledged characteristic; recent investigations have, however, shown that this is by no means an invariable occurrence.

Schönlein observes on this point that he feels bound to contradict the old physicians—that the lateritious sediment in the urine discharged at the termination of the paroxysm is a *signum pathognomonicum* of intermittents, and that it may serve for the purpose of distinguishing masked intermittents from similar forms of disease,—

because the urinary crisis exhibits itself in various forms, and in many epidemics is either altogether absent, or only forms the exception and not the rule. For instance, when the whole tendency of the disease is directed towards the skin, the crisis is uniformly exhibited through that medium, and a urinary crisis is either altogether absent or only occurs subsequently, during the non-febrile state; so that while a perfectly clear urine is discharged at the termination of the paroxysm, the sediment which has been noticed occurs on the following day.

Becquerel examined the urine in fourteen cases of intermittent fever, ten of which were of the tertian, two of the quartan, and two of the quotidian type. During the intermission the urine resembled the normal secretion, and the resemblance was closer in proportion to the shortness of the paroxysm and the length of the intermission: the average specific gravity was 1018.9. In many of the cases, the urine during the paroxysm assumed the inflammatory type, that is to say, it was scanty in quantity, highly coloured, and very acid, with or without sediments (either spontaneous or produced by nitric acid,) and having a mean specific gravity of 1023.5.

In other cases, in which the febrile paroxysms had been recurring for a length of time, the appearance of the urine changed with the prolongation of the disease; it became paler and less acid, and its specific gravity fell to 1014.7.

The changes produced in the urine by the prolongation of the disease was very striking in the case of a man aged 49 years, who was attacked with a quartan fever during convalescence from acute articular rheumatism. As long as the first disease lasted, the urine was inflammatory, but, on the accession of the second, it became paler, less dense, contained a good deal of mucus, and finally became alkaline: the return of the paroxysm did not produce any change in the character of the urine, which remained the same until the recovery of the patient.

In a young chlorotic girl who was attacked with quotidian fever, Becquerel found that the urine was pale, as is the case with chlorotic persons, and was rendered turbid by a large quantity of mucus equally during the intermissions and the paroxysms; but, at the same time, the acidity and density (1021.8—1023.1) were more considerable than is usually the case in chlorosis; and, on cooling, a copious white sediment of uric acid was thrown down.

Becquerel frequently observed turbidity or sediments (either spontaneous or by the addition of an acid) towards the close of intermittent fever, but not earlier. During the paroxysms themselves, the urine was observed to present several modifications. In the majority of cases it seemed to undergo no change during the three stages, that is to say, the urine passed towards the end of the cold stage closely resembled that which was passed during the other stages; sometimes in the cold stage it was deeply coloured, acid, and of rather high specific gravity, and it would retain these characters in

the hot stage; sometimes it would be slightly coloured, faintly acid, and of low specific gravity (1013·4) in the cold stage, and would be darker, more acid, and of higher specific gravity (1021·8) in the hot stage.

Becquerel occasionally observed sediments in the urine at the termination of the paroxysm, but they were by no means of constant occurrence: Andral observed the same. He only noticed them in those cases in which the fever was intense and prolonged, and terminated in a very abundant perspiration, or when it was complicated with functional derangements, or with congestion of certain organs.

The sediment formed in intermittent fevers is always composed of uric acid and urate of ammonia, in most cases combined with red colouring matter (uroerythrin.)

A very perfect crisis by the skin and kidneys is said to indicate an erythemic type of fever; an imperfect and slight one, occurring through only one of the secreting organs, a synochal type; and a colliquative crisis, a fever of a torpid character.

In a young man aged 23 years, who was treated in our hospital for quartan fever, the urine, at the end of the paroxysm, always threw down a copious, yellowish-red sediment. During the intermission it was secreted more copiously, was clear, of an amber-yellow colour, contained a few mucous flocculi, and had a slight acid reaction.

[The following table, drawn up by L'Heretier,¹ represents the mean composition of the urine in the different stages of this disease, as deduced from the analyses of the urinary secretion of twelve patients:

		Cold stage.	Hot stage.	Sweating stage.
Specific gravity	-	1017·330	1020·304	1022·620
Water	-	967·520	964·680	961·645
Solid constituents	-	32·480	35·320	38·155
Urea	-	9·845	9·015	7·624
Uric acid	-	0·660	0·980	1·029
Salts and organic matter	-	21·975	25·325	29·502

In all these cases the physical characters of the secretion were affected by the disease; in six other cases the urine remained apparently normal.]

Scorbutus et Morbus maculosus Werlhofii. (Land-scurvy.)

In scurvy the urine is ordinarily of a dark reddish-brown, and sometimes of an almost black colour. Although it is slightly acid as it passes from the bladder, it very soon becomes alkaline, and develops a strong and disagreeable ammoniacal odour. According to Schönlein, blood is frequently discharged from the urinary organs, and the urine then assumes a dark reddish-brown colour, in conse-

¹ *Traité de Chimie patholog.* p. 528.

quence of the presence of hæmato-globulin : in this case, it develops hydrosulphate of ammonia, and soon becomes putrid.

I have examined the urine in three well-marked cases of scurvy occurring in Schönlein's clinical wards ; two were men between thirty and forty years of age, and the third, a woman who had been delivered a few weeks previously. In the men, not only were the gums attacked, and the peculiar scorbutic odour observed in the breath, but the lower extremities were covered with numerous ecchymosed spots and petechiæ. The woman had a very cachectic appearance : her face was somewhat swollen ; the gums nearly destroyed, livid, and hemorrhagic ; the teeth loose (one having fallen out the preceding night,) and the breath almost unbearable. In its physical characters the urine was very similar in these three cases. At first it was scanty (eight to twelve ounces,) and of a deep dark-brown colour, as if bile-pigment or decomposed blood were present, which, however, was not the case. It was devoid of the peculiar sweetish odour of typhus-urine, but, after standing a few hours, developed a disagreeable ammoniacal odour.

The addition of ammonia produced a very slight turbidity ; and, on the addition of chloride of barium to the urine acidulated with nitric acid, the precipitated sulphate of baryta was much less than in healthy urine. The addition of ammonia (after the removal of the sulphate of baryta) produced a comparatively slight precipitate, showing that there was a deficiency of the phosphates. Infusion of galls, basic and neutral acetate of lead, and acetate of copper, produced considerable turbidity, and the urine was similarly affected (but in a much less degree) by bichloride of mercury. In their chemical characters, these three specimens closely resembled each other, and were found to approximate to the urine in typhus. The amount of urea was much less than in normal urine, not exceeding 25—30% of the solid residue. The fixed salts were diminished in the urine of the men, forming 14—18% of the solid residue, while in the woman they amounted to 27%, a little above the normal average (25%). The uric acid was slightly above the healthy standard in all the cases, ranging from 1—3% of the solid residue. The men rapidly improved under proper treatment ; the urine became more abundant and clearer, and, in the course of six days, was apparently normal. The woman recovered more slowly.

In a girl aged 20 years, treated in Schönlein's clinical wards for morbus maculosus Werlhoffii, I found the urine, during a period of a fortnight, of a dark brown colour, of a disagreeable ammoniacal odour, and with an alkaline reaction. It deposited a viscid sediment of earthy phosphates, urate of ammonia, and mucus. The addition of nitric acid indicated the presence of a small quantity of bile-pigment. Blood (of which the composition is given in page 259) issued from the mouth, exuding from red patches situated above the uvula. The odour of the breath was putrid. During her recovery, the urine returned to its original state.

[The urine in this disease has likewise been analyzed by Heller and Martin.

The two following cases are recorded by Heller:¹

1. A girl aged 19 years, marked over the whole body, was admitted into the clinical ward of Professor Lippich.

The urine was of an intensely yellowish-brown colour, rather turbid, and deposited flocks of mucus. The odour, at first ordinary, rapidly became ammoniacal; and the same tendency was observed throughout the course of the disease. Reaction faintly acid. Specific gravity 1021. The urine contained in 1000 parts:

Water	:	:	:	:	:	949-23
Solid constituents	:	:	:	:	:	50-72
Urea	:	:	:	:	:	16-21
Uric acid	:	:	:	:	:	1-27
Extractive matters with much hydrochlorate of ammonia	:	:	:	:	:	23-24
Fixed salts	:	:	:	:	:	9-80

The fixed salts consisted almost entirely of earthy phosphates and sulphate of potash, there being a mere trace of chloride of sodium. No albumen was present.

2. In a youth aged 16 years, the urine, during the progress of the disease, was of a brownish-yellow colour and turbid; and when an improvement manifested itself, the secretion became of a lighter tint, and clearer. A sediment of ammoniaco-magnesian phosphate and urate of ammonia was deposited during the disease, but gradually disappeared during convalescence. The urine had a faintly acid reaction, but, notwithstanding, evolved a putrid odour, and very rapidly became alkaline. The specific gravity was at first 1017, and subsequently varied from that number to 1012. Traces of albumen could always be detected till symptoms of convalescence appeared. In its chemical characters it resembled the preceding case. The hydrochlorate of ammonia was much increased, while the chloride of sodium was diminished to a mere trace. The uric acid was much increased, amounting to 2 in 1000 parts. The urine remained abnormal for six days, and then appeared to have resumed its ordinary character.

Heller observes that the augmentation of the ammonia (in the form of hydrochlorate) and of the uric acid, together with the diminution of the chloride of sodium,—characters seemingly associated with this disease,—indicate that the blood must be in a state of dissolution.

In Martin's² case, the secretion was very scanty, about one or two ounces being passed at a time, and the daily amount being from twelve to twenty ounces. In its physical characters it resembled the urine described in the preceding cases.

On evaporating the urine, and allowing the solid residue to remain for some hours at a temperature of 212°, there was remarked on the surface of the brown, and (for the most part) saline mass, a copious,

¹ Archiv für physiologischen und pathologischen Chemie, vol. 1, p. 12.

² Neue med.-chir. Zeit. 1845.

reticulated, dendritic efflorescence which, when examined with a lens, was found to consist of long, transparent, four-sided needles, with double-sided sharp extremities. They were proved to be neither hydrochlorates, sulphates, nor phosphates, and were presumed to be crystals of hippuric acid. Three analyses were instituted.

		1.	2.	3.
Specific gravity	-	1013-40	1021-26	1010-31
Water	-	984-42	973-74	985-730
Solid constituents	-	15-58	26-26	14-270
Urea	-	643	6-07	5-430
Green colouring matter (thrown down by hydrochloric acid in place of uric acid)	{	0-09	0-10	0-006
Extractive matters with ammonia-salts, &c.		2-34	2-25	0-650
Fixed salts soluble in water	-	6-30	17-00	7-794
" insoluble in water	-	0-42	0-84	0-390

Analysis 1 was made on Oct. 22d, before the administration of any remedies. The urine was faintly acid. The soluble salts consisted for the most part of chloride of sodium. Analysis 2 was made on the 3d of November with the mixed urine of the preceding twenty-four hours. It had a strong ammoniacal odour, but was perfectly neutral. The patient had taken sulphuric acid, iron, and other tonics, in the interval, without any obvious improvement, and traces of iron were found with the earthy phosphates. Analysis 3 was made with the morning urine passed on the 25th of November. The same treatment had been pursued with very decided benefit. The urine was clear, slightly yellow, and devoid of the unpleasant odour it previously evolved. Its reaction was faintly acid, and it contained traces of iron.

The green colouring matter is probably a compound of uric acid and biliphaein. A compound of this nature has been observed and described by Heller.^{1]}

Chlorosis.

The urine of chlorotic persons is usually pale, of low specific gravity, and of a mildly acid reaction: in these respects it resembles the urine of persons who have lost a considerable quantity of blood, or the form of urine termed nervous, which we sometimes observe in hysterical attacks.

Becquerel applies the term *anæmic* to this form of urine, and, as in the majority of cases in which it occurs, there is either an absolute deficiency of blood or a scarcity of the truly vital portion—the blood-corpuscles, no objection can be raised to such a designation. The urine in chlorosis has, however, other distinctive properties, as has been clearly shown by the researches of Becquerel; for it is very poor in urea, and in that respect resembles the urine in typhus, while it differs from the latter in containing only a small quantity of uric acid, and a large amount of fixed salts.

I may perhaps be allowed to refer once more to the intimate connexion subsisting between the action of the metamorphosis of the

¹ Archiv für phys. und pathol. Chemie, vol. 1, p. 99.

blood-corpuscles (or of their development and vitality) on the one hand, and on the production of urea on the other.

The proportion of the urea to the solid constituents of the urine in inflammatory diseases, in those forms of typhus which assume a torpid character, and lastly in chlorosis, affords us sufficient illustration of this connexion.

In the form of typhus to which we have alluded, as well as in chlorosis and anaemia, the urea is diminished; but, as we have already remarked, in that case the uric acid, which is a product peculiar to febrile action, is increased, and the salts (partly in consequence of the diet) are diminished; while in chlorosis, in which a nutritious nitrogenous diet is allowed, the diminution of the urea plainly indicates that the seat of the disease must be sought for in the production of the blood-corpuscles.

I shall now give Becquerel's account of the chemico-physical relations of the urine in chlorosis.

The quantity of urine emitted in twenty-four hours amounts to about 34 ounces. It is pale and of a greenish tint, and only becomes dark when the urine is very concentrated: the acid reaction is weak; uric-acid sediments are seldom formed; when they do occur, they are of a white or gray colour. If, as is not unfrequently the case, leucorrhœa is associated with chlorosis, the urine is more or less turbid in consequence of the mixture of the morbid product with it; in these cases a little albumen is generally observed.

The quantitative analyses which Becquerel made of the urine of chlorotic persons gave the following results:

		Anal. 1.	Anal. 2.	Anal. 3.
Quantity of urine in 24 hours	-	41.3 ounces	50.8 ounces	27.5 ounces
Specific gravity	-	1011.3	1012.6	1016.8
100 parts contained:				
Water	-	981.28	979.21	979.28
Solid residue	-	18.72	20.79	27.73
Urea	-	6.03	7.38	6.83
Uric acid	-	0.08	0.26	0.23
Fixed salts	-	4.80	8.05	8.45
Extractive matters	-	7.79	5.14	11.16

If we calculate the amount of urea, uric acid, and fixed salts in these analyses in relation to 100 parts of solid residue, and compare the results with the physiological average which Becquerel has given, the proportions to which I have already alluded will plainly appear, that is to say, there is an absolute and a relative diminution of urea and of uric acid, and an increase of the fixed salts: 100 parts of the solid residue contain:

		Anal. 1.	Anal. 2.	Anal. 3.	Normal Urine.
Urea	-	32.0	33.0	24.0	42.0
Uric acid	-	0.4	1.2	0.8	1.4
Fixed salts	-	26.0	38.0	30.0	24.0

The urine may exhibit some differences in its chemico-physiological properties if other diseases are associated with chlorosis, or if the latter is not very fully developed. The persons from whom the urine

in analyses 1 and 2 was taken were slightly feverish. In analysis 3, the chlorosis was combined with pulmonary emphysema. In analysis 4, there was some affection of the nervous system.

With the exception of a considerable diminution in the quantity of urine discharged in twenty-four hours in analyses 1 and 3, and the increase of uric acid in analysis 2, there are no particular deviations in the relative proportions of the solid constituents from the statement that we have previously made; for the urea is both absolutely and relatively diminished, and the salts occur in a higher proportion than in normal urine.

	1.	2.	3.	4.
Quantity of urine passed in } 24 hours, in ounces }	23.3 oz.	24.5 oz.	17.8 oz.	38.5 oz.
Specific gravity	1014.2	1017.6	1016.8	1016.8
1000 parts contained:				
Water	-	976.43	970.89	972.28
Solid constituents	-	23.57	29.11	27.72
Urea	-	8.37	7.81	8.64
Uric acid	-	0.20	0.81	—
Fixed salts	-	4.74	0.09	8.36
Extractive matters	-	10.34	11.47	10.24
				12.10

Becquerel has made some interesting remarks on the influence of ferruginous preparations on the urine in chlorosis.

In the majority of cases the iron is partially carried off by the urine; sometimes, without any apparent reason, it is absent from urine in which it is found on the preceding and succeeding days. The quantity of iron thus carried off in the urine of the same individual is subject to great variations; sometimes it can only be detected after the incineration of a portion of evaporated urine, while, on other occasions, the simple addition of a test is sufficient to indicate its presence. The iron begins to pass off by the urine from the commencement of the administration of the medicine, and it occurs in all the urine that is emitted; so that there is no necessity for the system to be saturated with it before any portion can pass off by the kidneys; as the assimilation of the iron is a very slow process, large doses merely derange the digestive organs without being of more service than smaller doses.

[Herberger¹ analyzed the urine of the chlorotic girl referred to in p. 257, and his analyses indicate the simultaneous diminution of the blood-corpuscles and urea. The urine was analyzed on three occasions before the use of iron, and twice afterwards.

Urine before the use of iron.

	1.	2.	3.
Specific gravity	-	1010	1009
Quantity in 24 hours	-	32 oz.	42 oz.
Water	-	975.43	978.21
Solid constituents	-	24.57	21.79
Urea	-	7.04	7.00
Uric acid	-	0.13	0.21
Extractive matters	-	10.48	9.00
Fixed salts	-	6.80	5.50
			13.99
			6.62

¹ Buchner's *Repertorium*, vol. 29.

Urine after the use of iron.

		^{1.}	^{2.}
Water	-	940-16	939-70
Solid constituents	-	59-84	61-30
Urea	-	26-84	27-36
Uric acid	-	0-94	0-96
Extractive matters	-	18-62	16-28
Fixed salts	-	13-32	15-71

Traces of iron were detected both in the sweat and urine during the period of treatment.]

Donné states that normal urine always contains a certain quantity of iron which disappears during chlorosis, and only reappears after the use of ferruginous preparations. This statement is contradicted by Becquerel, who has never been able to discover iron in the incinerated residue of normal urine, although ferrocyanide of potassium would evolve a bluish shade,—an effect which this test sometimes has on chlorotic urine.

[L'Heretier¹ gives the mean of eight analyses of the urine in uncomplicated chlorosis:

Quantity of urine	-	1000	In 24 hours. 38 oz.
Specific gravity	-	1011-9	—
Water	-	983-1	18372 grains
Solid constituents	-	16-9	316
Urea	-	6-6	123
Uric acid	-	0-2	5
Fixed salts	-	4-1	77
Organic matter	-	6-0	111

I am indebted to the kindness of Dr. Golding Bird for the following cases:

1. A girl aged 18 years, of anaemic appearance, and who had suffered from anasarca for six months, passed 30 ounces of acid urine of specific gravity 1024, in twenty-four hours.

The water amounted to	-	-	12690 grains.
The solids	-	-	750
Urea	-	-	162
Uric acid	-	-	9

She then commenced taking *ferri sulph.* gr. iij, *ter die*. In the course of a week the urine was again examined; it amounted to 20 ounces, had a specific gravity of 1029, and deposited urate of ammonia.

The water amounted to	-	-	8392 grains
The solids	-	-	608
Urea	-	-	137
Uric acid	-	-	20

The anaemia was now disappearing. At the end of the second week the amount of urine was 30 ounces, and the specific gravity 1023.

The water amounted to	-	-	12690 grains.
The solids	-	-	720
Urea	-	-	242
Uric acid	-	-	5

2. The urine of a girl aged 15 years, of chlorotic appearance but

¹ *Traité de Chim. patholog.* p. 551.

menstruating regularly, amounted to 25 ounces, and had a specific gravity of 1020.

The water amounted to	.	.	.	.	10637 grains.
The solids	.	.	.	.	519
Urea	.	.	.	.	231-25
Uric acid	.	.	.	.	25-00

The amount of uric acid in this case is very remarkable.]

Hemorrhages.

The properties of the urine in hemorrhages are entirely dependent, during the period of the discharge, and for some short time afterwards, upon the degree in which the vascular system participates in the general disturbance. In many cases, as, for instance, in cerebral and pulmonary hemorrhages, we find that the quantity of urine is diminished, its colour becomes deepened, its acidity and its specific gravity increased,—that is to say, it entirely resembles inflammatory urine. When there is hemorrhage from the kidneys, uterus, or any portion of the generative system, the urine will naturally contain blood, either in a state of solution or undissolved. If the hemorrhage is succeeded by a state of anaemia and great prostration of strength, the urine then becomes pale, of slight acidity, and of low specific gravity, as in chlorosis.

Becquerel made three examinations of the urine in cerebral hemorrhage, and in two of these cases he found it analogous in its physical relations to the urine of inflammation: in the third case, in which the patient had imperfect hemiplegia of the right side, but in other respects seemed well, the urine could hardly be considered abnormal.

In one of the first two cases, the urine was taken from a man aged 43 years, who was affected with perfect paralysis of the left side, and died on the fifteenth day from the seizure. It exhibited in a high degree, both in its physical properties and in its chemical constitution, the characters of inflammatory urine. The quantity was diminished; the specific gravity, the urea, and uric acid exceeded the physiological average.

Quantity of urine in 24 hours in ounces	.	.	.	.	25-7
Specific gravity	.	.	.	.	1023-1
Water	.	.	.	.	960-40
Solid residue	.	.	.	.	39-60
Urea	.	.	.	.	17-10
Uric acid	.	.	.	.	0-65
Fixed salts	.	.	.	.	10-00
Extractive matter	.	.	.	.	11-80

In 100 parts of solid constituents there are 43-0 of urea, and 1-6 of uric acid.

The urine of a man aged 31 years, who was treated in Schölein's clinical wards for a severe attack of pulmonary hemorrhage, was of a dark red colour, very acid, and exhibited the other symptoms of the inflammatory type, from the period of admission to the eleventh day. On two occasions I found its specific gravity to be 1029 and

1022. On the eleventh morning the urine was rather turbid, and on the twelfth it became jumentous from the urate of ammonia which was suspended in it; it still had a strong acid reaction, but did not form any sediment: on the next day, the sediment was very considerable. The pulse was quick and feverish till the urine began to deposit sediments; subsequently, the vascular excitement almost entirely disappeared, and the urine became clear and pale, and contained only a few mucous flocculi.

In a girl aged 20 years, with severe hæmatemesis, who had brought up nearly a quart of coagulated blood, the urine which was passed almost immediately after the attack scarcely differed from the normal secretion; but, on the following day, it was pale, and scarcely acid, and it continued in this state for several days.

In hæmaturia the urine contains blood, either in a coagulated state or devoid of fibrin; in the latter case, the blood-corpuscles may be either perfectly dissolved or not; and when they are found floating in the urine, they form, after a short time, a red sediment. More minute observations on this subject have been given in page 435.

Rayer has published a very interesting communication on an endemic hæmaturia that occurred in the Isle of France. Children of very tender age discharged blood with the urine; he relates, for instance, the case of a boy, who from his seventh year lost nearly an ounce of blood daily: uric-acid gravel was combined with the hæmaturia.

A man aged 21 years, from the Isle of France, who was under Rayer's care, had had hæmaturia from his youth. The urine which he passed in Rayer's presence formed, in the course of seven hours, a cream-like layer on the surface; two distinct strata were afterwards formed, the upper being of a yellowish-white colour, and the lower red: the latter contained two clots of coagulated matter, one was the ordinary blood-clot, the other was white and loose. The upper milky stratum contained much albumen and fat (chylous urine,) the lower one contained blood. No casein was present. It is worthy of remark, that the hæmaturia never came on till about noon, the urine passed in the earlier hours being always clear.

Rayer and Orfila also observed a similar case of bloody and milky urine in a Brazilian. The disease commenced with a discharge of milky urine, the hæmaturia coming on a year afterwards.

Catarrhs.

In simple catarrh the state of the urine corresponds with the degree of vascular reaction.

If the catarrh terminates without any perceptible fever, the urine scarcely deviates at all from the normal state: if the fever is accompanied by much excitement, the urine, according to Schönlein, becomes rather red, and forms a mucous sediment. At the commencement of convalescence from a feverish catarrh, the urinary crisis shows itself by a mucous sediment.

In influenza the urine assumes a reddish tint, and assumes more or less of the inflammatory type in proportion to the synochal character of the fever. Schönlein states that the nature of the urinary crisis at the approach of convalescence is dependent on the character of the fever: in erythemic fever the sediment is mucous, in synochal fever it is earthy, and in gastric fever it is of a yellowish-gray colour.

In measles, which are considered by Schönlein as the most highly-developed form of catarrhal disease occurring in the northern hemisphere, the urine changes with the varying stages of the disorder. In most cases it more or less resembles the inflammatory type, it is red (as in inflammatory measles,) acid, and sometimes jumentous (as in gastric measles,) or deposits a mucous sediment during the course of the morning (as in catarrhal measles.) Becquerel states, as the result of his observations, that the urine is generally inflammatory at the commencement of the febrile period. It becomes very dark and of high specific gravity, and frequently deposits a sediment of uric acid: a small quantity of albumen was found in a few of the cases. During the eruptive period the character of the urine changes; if the eruption is slight, and there is not much fever, it resumes the normal type; if the contrary is the case, the urine retains the inflammatory appearance. Becquerel did not meet with any case in which the urine was turbid or sedimentary towards the close of the eruptive stage.

During the period of desquamation and of convalescence, the urine either returns at once to the normal state, or continues turbid and sedimentary for some time, or becomes pale, clear, and anaemic.

In three cases anasarca came on during convalescence, but the urine did not contain albumen.

During the catarrhal affection of the mucous membrane of the stomach, or the *status gastricus* (as it has been called,) which when more fully established, becomes gastric fever, the urine is generally more or less turbid, and earthy sediments appear as symptoms of a crisis.

Becquerel found that the urine in "l'embarras gastrique" was often of a deep colour, and sedimentary, as in the phlogoses: sometimes, however, it hardly differed from the normal secretion. Out of twelve cases, the urine in two scarcely differed at all from the normal type, in the other ten it approximated more or less in its characters to the urine of inflammation: the deepness of the colour appeared to be always in relation to the intensity of the disorder, and to the presence of some degree of fever. In the twelve cases, with two exceptions, the urine was constantly acid. In one of the exceptions the urine was alkaline, and contained numerous crystals of ammoniacomagnesian phosphate. In six cases sediments of uric acid were formed either spontaneously, or on the addition of an acid: in two in which the symptoms were very intense, a little albumen was present, but in each case it lasted only one day. The mean specific gravity of the urine was 1021·4; the highest, and in this case a sediment was deposited, was 1025·2.

In gastric fever the urine is frequently turbid and jumentous: it usually contains urate of ammonia in suspension, and has an acid reaction. An earthy flocculent sediment occurs as a urinary crisis at the commencement of convalescence, the supernatant fluid being clear. (Schönlein.)

In mucous fever the urine is red and fiery, if the fever (which at the commencement assumes the intermittent type, and which only at a later period becomes continuous,) takes on a synochal character.

It is not unfrequently limpid and clear, as in hysterical cases, and forms, especially if the affection has extended to the genito-urinary mucous membrane, a mucous sediment. In those cases in which the urine is limpid, it assumes the normal colour during the progress to convalescence, and sediments are deposited which gradually become thicker, and pass from a mucous to an earthy-purulent character. (Schönlein.)

The urine in bilious fever is usually impregnated with bile-pigment; it is of a more or less brownish colour, and when a thin layer is seen it appears of a citron-yellow tint: it differs, however, with the degree of vascular excitement; if the fever has a synochal character the urine is dark and of a fiery-red colour, if the fever is erythemic, which is frequently the case, it is of a dark yellow or yellowish-brown colour, and in torpid fever it is more or less brown, and not unfrequently mixed with blood. The presence of bile-pigment may always be recognised by the change of colour which succeeds the addition of nitric acid.

Cholera.

In sporadic cholera, as well as in the Asiatic form of the disease, the urinary secretion is very scanty, and sometimes altogether suppressed. Any urine that is discharged is usually of a dark colour, and has a feeble acid reaction, but its specific gravity is below the healthy average.

In a case which I observed in our hospital, where the symptoms were exhibited with great severity in a woman 36 years of age, there were frequent evacuations by stool, but only about one ounce and a half of dark acid urine, with a specific gravity of 1011·0, in the course of twenty-four hours. I only determined the amount of solid constituents collectively, and of the urea.

In 1000 parts I found:

					Analysis 118.
Water	:	:	:	:	975·90
Solid constituents	:	:	:	:	24·10
Urea	:	:	:	:	7·10

The urea in this case amounts to rather more than 29% of the solid residue, which is considerably below the normal proportion. At the approach of convalescence the urine was discharged more copiously, but it continued to be deeply coloured: it was only after some days that it became pale and anaemic. I never observed any sediment.

[The urine of a man aged 30 years, attacked with sporadic cholera, was analyzed by Heller.¹ There was excessive diarrhoea and vomiting, and the patient died on the fourth day.

During the first forty-eight hours of his illness only one ounce of urine was discharged; it had a deep golden-yellow colour, and deposited earthy phosphates although strongly acid. Its specific gravity was 1018. It contained in 1000 parts:

Water and free carbonic acid	-	-	-	-	-	955·67
Solid constituents	-	-	-	-	-	44·33
Urea	-	-	-	-	-	10·50
Uric acid	-	-	-	-	-	0·10
Extractive matter, with a large quantity of a peculiar substance apparently originating from the bile	-	-	-	-	-	27·32
Fixed salts	-	-	-	-	-	6·41]

We are unfortunately not possessed of any trustworthy information respecting the urine in Asiatic cholera. R. Herrmann² has communicated the following remarks.

As no opportunity occurred for obtaining urine passed during the more urgent stages of the disease, that which was first discharged by a patient who was just getting over a severe attack was analyzed: it was yellowish, turbid, deposited no sediment, had a neutral reaction, and by the application of appropriate tests, the presence of phosphates, hydrochlorates, and ammonia-compounds was indicated; on the addition of nitric acid, crystals of nitrate of urea were obtained; but only small quantities of all those substances were present. Its specific gravity was very low, being only 1006.

Wittstock³ has likewise instituted some researches on the urine which was passed immediately after an attack of cholera. It had a specific gravity of 1008·5, was neutral, of a pale yellow colour, but not perfectly transparent, in consequence of microscopic crystals (consisting, in all probability, of ammoniaco-magnesian phosphate,) held in suspension. The sides of the glass were also covered with minute glittering crystals, which were supposed by Wittstock to consist of uric acid, but which, in all probability, were composed of ammoniaco-magnesian phosphate also.⁴

An interesting investigation regarding the urine in cholera has also been made by Vogel. The urine was passed after the most violent symptoms had abated: it was of a deep brownish-yellow colour, was rather turbid, deposited no sediment, had a specific gravity of 1008·0, and indicated a strong acid reaction. The salts of lime and magnesia were entirely wanting, and the quantity of chloride of sodium was very minute, while on the other hand the sulphates were found in a larger proportion than in normal urine.

The existence of bile-pigment and of albumen was proved by the

¹ Archiv für phys. und pathol. Chemie, vol. 1, p. 15.

² Poggendorff's Annalen, vol. 22, p. 176.

³ Cholera Archiv, vol. 1, p. 428.

⁴ It is by no means probable that urine, with so low a specific gravity, and especially when it is alkaline or neutral, should throw down a precipitate of uric acid; a sediment of urate of ammonia would be much more probable. The neutral state of the urine would favour the separation of crystals of ammoniaco-magnesian phosphate, as suggested in the text.

addition of nitric acid to the urine. Urea, uric acid, mucus, and a good deal of phosphoric and lactic acid were present. Subsequently the albumen and bile-pigment disappeared, and the earthy phosphates returned.

In vesical catarrh the urine is generally very pale, and always contains a greater or less amount of mucus. The feeble acid reaction which it possesses at the period of its emission is frequently lost in a very short time, and it becomes neutral or alkaline, and a quantity of the earthy phosphates (especially of crystals of ammoniaco-magnesian phosphate,¹) becomes mixed with the mucus. The quantity of mucus which is separated is sometimes very bulky.

Schönlein remarks that we may possibly be able to determine the seat and the extent of the blennorrhœa from the quality and the amount of mucus. Mucus secreted from the mucous membrane of the bladder forms a uniform mass, and is tenacious and thready, while that secreted by the mucous membrane of the ureters and of the pelvis of the kidney is, on the contrary, flocculent: if the tenacious and the flocculent forms of mucus are both found at one and the same time, we are justified in assuming that the bladder, ureters, and pelvis are simultaneously affected. Willis² in speaking of cystorrhœa, states that in acute vesical catarrh accompanied by inflammatory fever, the urine is scanty and highly coloured, and precipitates a much greater quantity of tenacious mucus than usual; also that in the earlier stages of the disease it is sometimes ammoniacal, but more frequently when the disease has continued for a long time. In chronic vesical catarrh the urine is flocculent when it is passed; the flocculi increase with the advances of the disease, and collecting at the bottom, form a tenacious mass which may be drawn out into threads; this mass sometimes assumes the consistence of bird-lime, and exhibits spots of blood.

As the disease advances still further, we often find a fourth or even a third part of the urine to consist of mucus, so that six to eight or even ten ounces are daily thrown off. Willis inquires whether this secretion is always composed of actual mucus, or whether pus in a modified form is not always present.

In the urine of a man who was being treated for catarrhus vesicæ in our hospital, I found a very bulky sediment composed of mucus and earthy phosphates: the quantity of ammoniaco-magnesian phosphate was also very considerable.

The urine upon becoming clear above the sediment, was of a faint yellow colour, and contained much carbonate of ammonia; it constantly had an alkaline reaction. The sediment for a period of eight days assumed a faint grayish-blue colour; when washed (for the purpose of separating the urine from it as completely as possible,) and dried, it was treated with anhydrous alcohol, which took up the blue

[It is worthy of observation that beautiful crystals of ammoniaco-magnesian phosphate may occasionally be found in urine with a decidedly acid reaction.]
Primary Diseases and their Treatment, p. 399.

colouring matter, and on evaporation left it as a beautiful blue substance insoluble in water, but dissolving in ether with a reddish tint. I can only compare it to Braconnot's cyanourin.

Rheumatism.

We have already seen that the blood in rheumatism perfectly corresponds with the blood in the true inflammations; hence we are led to infer that the urine will also present the inflammatory type—an inference confirmed by experiment.

The urine in acute rheumatism, (when the reaction is accompanied by synochal fever,) exhibits in a high degree those characters of inflammatory urine which I have already so often described. The colour is sometimes deep purple-red, like claret, its acid reaction is very strongly developed, and very bulky, fawn-coloured or lateritious sediments, consisting for the most part of urate of ammonia, but occasionally of crystallized uric acid, are deposited. The extent to which these properties of the urine are exhibited depends upon the violence, and the more or less synochal character of the fever.

Vauquelin and Henry found free phosphoric acid, and the latter also free acetic acid, in the urine.

In chronic rheumatism without fever, the characters of inflammatory urine may be altogether absent, and instead of the earthy sediments we shall have merely a cloudiness and turbidity, as I have observed in my own case. The urine which I have passed during the night has frequently remained perfectly clear, while that discharged in the course of the day often formed only slight deposits. As the urine in rheumatism often throws down sediments even at the height of the disease, the deposits which are formed can only be regarded as significant of a true crisis when the supernatant urine is perfectly clear. Eisenmann¹ remarks that the properties of the urine may undergo a change if the disease continues for a long time; for instance, if it should take a hypodynamic character, the urine, instead of being acid, will assume an alkaline reaction, and will give off a fetid ammoniacal odour.

When the disease takes on the hypodynamic type, without having previously exhibited a hyperdynamic character, the urine, instead of being red, is then, according to Stork's observations, pale, frequently thick, turbid, and fetid.

Becquerel has made quantitative analyses of the urine in several cases of rheumatism. He found the relative proportions of the solid constituents the same as in inflammation—a fact that had been previously observed by Henry,² who found a large amount of urea in his own urine during rheumatic fever.

The urine of a man aged 30 years (Anal. 1,) who had been bled for acute rheumatism, was very deeply coloured, and on the addition of a little nitric acid threw down a copious sediment. It also threw

¹ Die Krankheitsfamilie Rheuma, p. 51.

² Journ. de Pharm. 15, p. 228.

down a spontaneous sediment of a reddish colour after standing for two hours. The specific gravity was 1017.2. The urine of the same man was analyzed another day, (Anal. 2.) It was of a very dark colour, almost like blood, and had a specific gravity of 1018.0. The urine in the third analysis was taken from a man aged 38 years, whose pulse was 104 in the minute. It was of a yellowish-red colour, and threw down a sediment of uric acid on the addition of a few drops of nitric acid.

	1.	2.	3.
Water	971.80	970.20	981.10
Solid constituents	28.20	29.80	18.90
Urea	12.20	9.00	8.00
Uric acid	1.70	1.04	0.50
Fixed salts		5.59	2.34
Extractive matter		14.70	8.00

If we calculate the amount of urea and of uric acid in proportion to 100 parts of solid residue, we obtain 43% urea and 6% uric acid in the first, but only 31% urea, and 3.5% uric acid in the second analysis; so that in the first analysis the physiological average is exceeded, while in the second it is not reached, at least as far as the urea is concerned.

In the third analysis the numbers approximate closely to the physiological average, viz. 42% urea and 2.6% uric acid.

In eighteen cases of rheumatism, in which the renal secretion was examined by Becquerel, it always assumed to a greater or less degree the characters of inflammatory urine during the continuance of the fever: the very deep colour was general, as also the acid reaction, except in one case, in which for a single day an alkaline reaction was observed. The mean specific gravity was 1022.6: in those cases which threw down a spontaneous sediment it was 1035.2. In twelve out of the eighteen cases, a spontaneous sediment was thrown down during the febrile period: these sediments usually alternated with dark but clear urine, or with urine that was precipitable by nitric acid.

Albumen was detected in seven of the eighteen cases. During the period of convalescence the urine was anaemic, or returned to its normal state.

[The following analysis of the urine of a man aged 22 years, suffering from acute rheumatism, was made by Dr. Baumert.¹ The urine submitted to analysis was passed on the fourteenth day of the disease. It was of a deep yellowish-brown colour, but perfectly clear. In the course of twenty-four hours it deposited a copious sediment of urate of ammonia, but did not become alkaline.

It presented the normal degree of acidity, and its specific gravity was 1028.3. It contained in 1000 parts:

Water	:	:	:	:	:	928.68
Solid constituents	:	:	:	:	:	71.32
Urea	:	:	:	:	:	18.65

¹ Archiv für phys. und patholog. Chemie, vol. 1, p. 45.

Uric acid		0.86
Extractive matter with a large quantity of hydrochlorate of ammonia	{	37.61
Fixed salts		14.20

The fixed salts contained no trace of chloride of sodium, the normal amount of earthy phosphates, a slight excess of alkaline phosphates, and an augmentation of the sulphates.

Hippuric acid was sought for without success.

Oxalate of lime is of frequent occurrence in cases of acute rheumatism.]

In chronic rheumatism, if the pains are not very acute, and the night's rest is not disturbed, the urine retains its normal properties. Out of thirty-seven cases observed by Becquerel, the urine remained unaffected in twenty, while in seventeen it assumed the inflammatory type, and in nine of these threw down a spontaneous sediment.

Gout.

I have made four analyses of the urine in two cases of gout, with the view of determining the effect of benzoic acid on that secretion:

	Before administration. Anal. 119.	After ditto. Anal. 120.	Before administration. Anal. 121.	After ditto. Anal. 122.
Water	976.73	979.84	965.25	962.43
Solid constituents	23.27	21.16	34.75	37.57
Urea	7.02	6.10	9.23	10.00
Uric acid	0.50	0.48	0.58	0.60
Earthy phosphates	0.35	—	0.28	—
Sulphate of potash	2.67	—	2.08	—
Phosphate of soda	1.60	—	4.53	—
Hippuric acid	—	0.65	—	0.69

If we determined the per centage of the urea and uric acid in relation to the solid residue, we find in the first case, that before the use of benzoic acid the urea amounted to 30.16% and the uric acid to 2.14%, and afterwards they amounted to 28.21% and 2.22% respectively. In the second case the urea and uric acid amounted to 26.56% and 1.66% before the use of the acid, and 26.61% and 1.59% afterwards.

These analyses are insufficient to show that benzoic acid exerts any influence on the amount of urea or uric acid. The clinical experiments of Froriep and others indicate, however, that it is a valuable remedy in various forms of arthritis.

Froriep¹ has published a notice of twenty cases of gout and chronic rheumatism in which he administered benzoic acid. During the first twenty-four hours the symptoms are always aggravated, but they usually subside on the second day.

The Exanthemata.

In all the acute exanthemata the urine very frequently presents, as Schönlein remarks, a peculiar character, which is due, in many

¹ Simon's Beiträge, p. 204.

cases, to an admixture of bile-pigment: it has a dark-brown colour, and resembles badly-fermented beer in appearance. At the commencement of the crisis the urine becomes clearer, and forms a pulverulent sediment consisting of uric acid (and perhaps urate of ammonia.)

In the fever which accompanies erysipelas, and is usually of an erethismic or synochal character, the urine is frequently loaded with bile-pigment, and is of a reddish-brown or red colour. At the urinary crisis, fawn-coloured precipitates are deposited, and the urine becomes clear. (Schönlein.)

Becquerel has examined the urine in several cases of erysipelas.

When the erysipelas is accompanied by fever, as is most commonly the case, the urine assumes the inflammatory type. Becquerel made two quantitative analyses of the urine of a man aged 39 years, who had erysipelas of the face, and a good deal of fever (pulse 112.)

The urine of the first analysis was of a deep yellowish-red colour, and clear; its specific gravity was 1021·0.

The urine of the second analysis was so deeply coloured as to appear almost black; it threw down a reddish sediment of uric acid, and had a specific gravity of 1023·1.

The first analysis was made on the fourth, and the second on the sixth day from the commencement of the disease.

These analyses gave:

		Anal. 1.	Anal. 2.
Quantity of urine passed in 24 hours, in ounces	.	27·0	30·6
Water	- - - - -	965·5	961·9
Solid constituents	- - - - -	34·5	38·1
Urea	- - - - -	12·5	12·7
Uric acid	- - - - -	1·2	1·3
Fixed salts	- - - - -	—	8·2
Extractive matter	- - - - -	—	15·9

In a woman aged 45 years, with erysipelas of the face, whose pulse was 104 and full, the urine was very scanty, of a dark-brown colour, strongly acid, threw down a yellow sediment spontaneously, and had a specific gravity of 1023·1.

It contained:

Water	- - - - -	961·7
Solid constituents	- - - - -	38·3
Urea	- - - - -	11·7
Uric acid	- - - - -	1·3
Fixed salts	- - - - -	9·2
Extractive matters	- - - - -	15·7

In five cases in which the morning urine was daily examined with care, the characters of inflammation were present in a very high degree: the specific gravity varied from 1021 to 1025. In four of these cases the urine threw down a reddish sediment, and in two a little albumen was occasionally present.

In scarlatina, the urine at the commencement, while there is considerable fever, is of a deep dark-red colour, and possesses all the properties of inflammatory urine.

In children the urine is always less coloured than in adults, and its colour in this disease is proportionally less dark.

It almost always has an acid reaction, and only exhibits a tendency to become rapidly ammoniacal, when the disease is associated with a nervous or septic condition of the system. Any sediments that may be formed, consist, for the most part, of urate of ammonia and uric acid mixed with a greater or less quantity of mucus: blood-corpuscles are occasionally noticed. When the urine is ammoniacal, viscid whitish sediments of the earthy phosphates are deposited, and if there is much gastric disturbance the urine becomes jumentous. Albumen is commonly, but not always found in the urine during the period of desquamation. Dropsy may even supervene without the urine becoming albuminous: it is sometimes preceded by the occurrence of haematuria.

Becquerel found that the urine during the febrile period was generally very high-coloured, and, if severe angina was present, was very acid, and was either turbid, or became so on the addition of an acid: it frequently also formed a gray or lateritious sediment, and the presence of a small quantity of albumen was by no means rare. Becquerel only observed blood in the urine in the single case of a child five and a half years old, who was attacked with anasarca. In a girl whose nervous system was very much deranged during the period of the febrile invasion, the urine was very deeply coloured, turbid, and deposited on the sides of the vessel a copious precipitate of a bright red colour. The sediment disappeared when the eruption was fully established. Blood was frequently observed in the urine when there were symptoms of impending dissolution during the nervous form of scarlatina; the quantity was sometimes very considerable, and the corpuscles could be readily detected by the microscope. The appearance of blood in this state must be distinguished from that in which it arises from a renal affection (Bright's disease) in which Becquerel has frequently observed it, and where, in the fatal cases, the existence of Bright's disease was proved. The amount of albumen in the urine is, in these cases, constant, and larger than is frequently found in inflammatory diseases, without the occurrence of any simultaneous dropsical symptoms.¹ During the period of desquamation symptoms of dropsy frequently supervene, and the urine often contains albumen, in larger amount and more continuously than is usually the case in inflammations.

The observations regarding the presence of albumen during the period of desquamation after scarlatina are so contradictory that it has become a matter of very great interest to settle these conflicting statements by further researches. We have dropsical symptoms with albuminuria, dropsical symptoms without albuminuria, and albuminuria without dropsical symptoms. Solon found albumen in the urine in twenty-two out of twenty-three cases of scarlatina. On

¹ When the urine contains no blood-corpuscles visible by the microscope, dissolved haemoglobin may be present, which can be estimated in the manner described in p. 436.

the other hand, Philipp¹ observed, in Berlin, where scarlatina was recently very prevalent, and aquasarca could not be warded off, at least sixty cases in which the urine was tested both with heat and nitric acid, and no trace of albumen could be detected.

In two cases of scarlatina that were being treated in Romberg's clinical ward for children, and in which there were no dropsical symptoms, I could find no albumen. In the case of a man aged 20 years, which occurred in Schönlein's clinical wards, the urine was very albuminous during the period of desquamation, and continued so for four days without the occurrence of dropsy; in another man, in whose urine I found no albumen, there were also no dropsical symptoms.

In a boy aged 5 years, who was suffering from septic scarlatina just then at its acme, (putrid odour from the mouth and nose, and disturbance of the cerebral faculties,) the urine was of a dark-yellow colour, had an alkaline reaction, a very disagreeable ammoniacal odour, and threw down a dirty white sediment of earthy phosphates, urate of ammonia, and urate of soda;—the latter occurring in the form of opaque globules. The specific gravity was 1022, and about 16 ounces were discharged in the course of twenty-four hours. There were contained in 1000 parts:

	Analysis 123.
Water	943-60
Solid constituents	56-40
Urea	19-35
Uric acid	1-69

The uric acid was combined with ammonia and soda. I examined the urine of the same boy afterwards, and found that it possessed precisely similar characters: it was of a straw-colour, had an alkaline reaction, and an ammoniacal odour; the sediment was more copious than on the former occasion, and there were considerably more of the large opaque globules, which I consider to be urate of soda. During the period of desquamation I found a greater number of mucus-corpuscles in the sediment than is usual, but nitric acid gave no indication of albumen. The urine above the sediment remained turbid in consequence of holding in suspension a very large quantity of epithelium, which was swimming about, partly in single scales, and partly in fragments of 8-12 scales connected with each other, and all of which were acted on by some chemical agent, probably by the carbonate of ammonia in the urine.

This sediment should always be sought for with as much care as albumen. It is an indication of the desquamation of the mucous membrane, and is frequently a precursor of the desquamation of the cuticle. The tubes described as occurring in Bright's disease are occasionally found in this form of sediment.

In variola and varicella the urine changes with the various stages of the disease, and with the nature of the fever which is present.

¹ Casper's Wochenschrift, 1840; No. 35.

Urine of a synochal character is, however, often met with, especially during the first stage of the disease, when the fever has a synochal type.

Becquerel examined the urine of eleven persons with variola, and of ten with varicella. In a case of varicella in which the early symptoms (les prodromes) were extremely severe, the urine was passed in very small quantity, of a deep red colour, and a specific gravity of 1022.7.

In a case of varicella in which the early symptoms were scarcely perceptible, the urine remained normal. Schönlein states that in the first stage of this disease the urine is often as limpid as in hysteria. During the eruptive stage, the state of the urine depends upon the intensity of the fever which accompanies the appearance of the exanthema.

In five out of the eleven cases of variola observed by Becquerel, the symptoms accompanying the eruption were very severe; the urinary secretion was diminished, and amounted on an average to only 23.5 ounces in twenty-four hours. The specific gravity had not, however, increased so much as might have been supposed, being only 1020.6. It frequently threw down uric-acid precipitates, either spontaneously, or on the addition of nitric acid, and in one case a little albumen was observed.

M. Solon found the urine coagulable in five out of eleven cases of variola. When the inflammatory symptoms, during the eruption are slight, the urine hardly differs from the normal state. During the suppurative stage of variola, Becquerel observed that the urine retained the synochal character as long as the febrile symptoms continued, in all the eleven cases. In three of these cases which terminated fatally, it continued in this state to the last.

During the period of desquamation the urine is either normal or anaemic. Becquerel states that although the urine during desquamation after variola resembles, in its chemical constitution, the urine during desquamation after varicella, it differs in respect to colour, the former being of a greenish, the latter of a yellowish tint. According to Schönlein, in the first stage of variola it is of a reddish brown tint; on the third or fourth day a sweat of a peculiar and strong odour is observed, and the urine contains a turbid, apparently purulent, mucous sediment, of an unpleasant odour.

During the period of suppuration, sediments, and frequently purulent mucus, are thrown down.

In the nervous form of variola the urine is even more changeable, being sometimes spastic, and sometimes dark. In the putrid form the urine appears decomposed, ammoniacal, and not unfrequently of a dark red colour from the presence of haematin.

Scrofulosis.

The urine of children with the scrofulous diathesis differs considerably in the majority of cases from the normal secretion. It is

usually pale, but if there is much vascular excitement it becomes more or less deeply coloured; its specific gravity is lower than in a state of health, and in many cases it is much more acid than the urine of children is generally observed to be; it has, however, been found neutral.¹ I have found the urine of rickety children only slightly acid, and once, after it had been passed some hours, it had an alkaline reaction. There are differences of opinion with regard to the nature of the free acid; some state that it is phosphoric acid, others hydrochloric acid, while others, again, are of opinion that it is lactic acid. The urea and uric acid are frequently found to exist in a diminished proportion; on the other hand, the salts, especially the phosphates, are increased; moreover, we not unfrequently find in the urine of scrofulous children an acid which is foreign to the normal organism, viz. oxalic acid.

According to Schönlein, the principal chemical changes in the urine of scrofulous persons consist in the diminution of the nitrogenous constituents,—the urea and uric acid, and in the appearance of the non-nitrogenous oxalic acid, and occasionally but more rarely of benzoic acid. The acids are frequently so abundant that the urine, upon cooling, deposits copious sediments of the oxalates, and these sediments sometimes form renal and vesical calculi within the organism itself. The frequent occurrence of oxalate-of-lime or mulberry calculi in children is well known; indeed, Prout is of opinion that half the stone-cases occur before the full age of puberty.

Becquerel has examined the urine in many cases of scrofula, in some of which it showed itself in the form of caries, necrosis, &c.; while in others it appeared in suppuration of the glands. A number of these children were in an anaemic state, while others were apparently in good condition; in the former cases the urine was anaemic, in the latter it was normal. The specific gravity varied from 1010 to 1022. The lowest specific gravity occurred in the anaemic cases. The colour was lighter than that of normal urine, and was frequently of a greenish tinge; the degree of acidity varied extremely, the urine frequently becoming alkaline after a very short time. No uric-acid sediments were observed, either spontaneous, or after the addition of an acid. When febrile symptoms were combined with those of scrofula, the urea approximated to the inflammatory type; its specific gravity became higher, (the average of twelve cases being 1026,) the colour deeper, it had a very acid reaction, and threw down a sediment of uric acid.

In scrofulosis of the osseous tissue or rachitis, the urine varies very much in its composition from the normal type. These deviations principally consist in the diminution of urea and of uric acid, and in the increase of the salts. The colour of the urine is generally either pale, or else it differs but little from the normal appearance; the free acid sometimes increases to an extraordinary degree, and some (Fourcroy) maintain that it is free phosphoric acid. The phosphates

¹ Stark Allg. Patholog. p. 1147.

exceed the physiological average, and moreover a considerable sediment of oxalate of lime is by no means rare. This extraordinary and morbidly-increased capacity of the kidneys for the removal from the blood of those salts which are so essential for the structure of the osseous tissue, and the consequent tendency to the formation of calculi in rachitic children, is regarded by Walther as a vicarious act of the kidneys in connexion with the formation of bone.

The urine of a child aged 5 years, who was being treated for rachitis in Romberg's clinical ward for children, was sent to me for analysis. It was of a pale-yellow colour, turbid and neutral; its specific gravity was 1011. As the determination of the salts was the principal object that I had in view, it was allowed to stand for two days before the analysis was undertaken; hence the determination of the urea may not have been perfectly accurate. The urine in the other analysis was passed by children aged 3 and 4 years respectively. It was much about the same colour as, or perhaps rather darker than in the first case, was slightly acid, and the specific gravity varied from 1015 to 1020.

The proportion of the most important constituents was found as follows:

	Anal. 124.	Anal. 125.	Anal. 126.	Anal. 127.
Water	978.40	968.50	964.90	962.80
Solid constituents	21.60	31.60	35.10	37.20
Urea	3.50	6.70	6.17	7.36
Uric acid	(¹)	0.26	0.35	0.26
Fixed salts	8.53	8.60	14.71	16.70
Phosphate of soda	2.82	4.01	4.27	3.74
Sulphate of potash	1.90	1.80	1.31	1.80
Earthy phosphates	0.48	0.52	0.58	—

On calculating the ratios of these constituents to 100 parts of solid residue, and comparing them with those that occur in healthy urine, we find that the quantity of urea has considerably decreased, while that of the salts is increased. In analyses 124, 126, 127, the increase of the fixed salts is very considerable, especially of the phosphate of soda and earthy phosphates. In analysis 125 this increased ratio is less striking. 100 parts of solid residue contain:

	Anal. 124.	Anal. 125.	Anal. 126.	Anal. 127.	Normal Urine.
Urea	16.1	21.2	17.6	19.8	39.0
Uric acid	—	0.8	1.0	0.7	1.5
Fixed salts	39.4	27.3	41.8	44.8	25.0
Phosphate of soda	13.0	12.7	12.1	10.0	10.0
Earthy phosphates	2.2	1.6	1.6	—	1.5
Sulphate of potash	8.7	5.7	3.8	4.8	8.0

In order, however, to arrive at a correct conclusion from these figures, we must bear in mind that the urine of children naturally contains a less proportion of urea and of salts than the urine of adults.

In osteomalacia the urine is much the same as in rachitis; it is very acid, and often contains an excessive amount of earthy phosphates.

[Marchand^a analyzed the urine of a child with osteomalacia three

^a The uric acid was not determined.

^b Lehrbuch der physiolog. Chemie, p. 338.

days before its death. The fluid was invariably acid, and contained in 1000 parts:

Water	-	-	-	-	-	939.2
Solid constituents	-	-	-	-	-	61.8
Urea	-	-	-	-	-	27.3
Uric acid	-	-	-	-	-	0.9
Lactic acid and lactates	-	-	-	-	-	14.2
Phosphates of lime and magnesia	-	-	-	-	-	5.7
Other substances, and loss	-	-	-	-	-	13.7

The earthy phosphates, in this instance, are five or six times as abundant as in health. In one of the cases recorded by Mr. Solly,¹ there was found in the urine between three and four times the amount of phosphate of lime that occurs in the healthy secretion.]

Tubercular pulmonary phthisis.

In tubercular phthisis the urine varies in accordance with the progress of the disease and the degree of fever which is present. I have observed in the majority of cases that after the febrile symptoms have become continuous the urine has assumed the inflammatory type; that is to say, it is not so deeply coloured as at the height of acute inflammation, but it is of a yellowish-brown colour, has a tolerably acid reaction, and is above, or at any rate attains the ordinary specific gravity.

In the early stages of the disease I have not found the urine to differ much either in colour, density, or acidity from the normal secretion. I have only observed that form of urine to which the term anæmic has been applied when considerable haemoptysis has occurred in the second or third stage. After haemoptysis the urine is generally turbid, and for the first day or two throws down slight sediments of urate of ammonia; it afterwards becomes pale and clear, and continues acid, gradually returning to its normal state. When the febrile symptoms become continuous and the colliquative stage has fairly commenced, I have found the urine approximate in its composition to the urine of inflammation.

Becquerel has examined the urine in a great number of phthisical cases. When the disease is progressing beyond the first stage, the urine is often of higher specific gravity, darker, and secreted in less quantity than usual,—a symptom that the tubercles are extending, and that a state of continuous fever is supervening. The subsequent phenomena of the morning sweats and colliquative diarrhoea further contribute to the concentration of the urine. When, however, a state of decided asthenia has been brought on by these extraordinary drains upon the system, it rapidly assumes opposite properties, and becomes anæmic. Thus the urine of a woman, in whom the tubercles were beginning to soften, and who had at the same time certain symptoms of disease of the heart, was found by Becquerel to amount to 20 ounces in twenty-four hours. It was of a deep yellow colour, threw down

¹ Transactions of the Medico-Chirurg. Society, p. 448, 1844.

a sediment of uric acid, had a specific gravity of 1022·2, and 1000 parts contained 36·5 of solid residue.

In a woman in the third stage of phthisis with great prostration of strength, the urine, three days before her death, was of a deep colour, acid, and threw down a spontaneous sediment. The specific gravity was 1014·7, and 16·2 ounces were discharged in twenty-four hours. 1000 parts contained:

Water	:	:	:	:	975·95
Solid constituents	:	:	:	:	24·05
Urea	:	:	:	:	9·00
Uric acid	:	:	:	:	1·25

In another precisely similar case the urine, three days before death, was of a deep colour, acid, and threw down a sediment spontaneously. The specific gravity was 1014·7, and there were only 7·2 ounces passed in twenty-four hours.

1000 parts contained 24·25 of solid residue, of which 9·01 was urea, and 2·2 uric acid. In the first of these cases the urea amounted to 37·4% of the solid residue, and the uric acid to 5·1%; in the second the urea amounted to 37·2%, and the uric acid to 9%,—proportions which, as far as the amount of urea is concerned, approximate to those of inflammatory urine.

An analysis of the urine of a man aged 30 years, who was in the colliquative stage of tubercular phthisis, gave very similar results, except as regards the specific gravity.

The urine was brown and turbid, had a very acid reaction, and deposited a purulent-looking yellow sediment of urate of ammonia. The specific gravity was 1026·6.

1000 parts contained:

Analysis 128.					
Water	:	:	:	:	935·92
Solid constituents	:	:	:	:	64·08
Urea	:	:	:	:	23·90
Uric acid	:	:	:	:	2·40
Fixed salts	:	:	:	:	10·85

Of these 10·85 parts of fixed salts 1·3 were earthy phosphates, and the sulphates formed only a small part. The urea amounted to 37·3%, and the uric acid to 3·7% of the solid constituents, the urea being as nearly as possible the same as in Becquerel's analyses.

The increase of uric acid is of great interest; it is particularly striking in Becquerel's analyses: other observers have noticed this fact in adults suffering from tubercular phthisis, and Schölein, moreover, has directed attention to it.

[I am indebted to Dr. Golding Bird for the following case. A man aged 24 years, in the early stage of phthisis, (tubercular depositions, but no cavities,) passed, in the course of twenty-four hours, forty-five ounces of urine of specific gravity 1020.

The water amounted to	:	:	:	:	19125 grains.
The solids	:	:	:	:	936
Urea	:	:	:	:	328·5
Uric acid	:	:	:	:	45]

In renal and vesical phthisis the urine contains a greater or less quantity of pus.

It is usually pale, turbid, and very quickly takes on an alkaline odour, especially in phthisis vesicæ, in which, even on emission, it is ammoniacal, and of an unpleasant odour. The pus is sometimes mingled with blood. That the clear filtered urine always contains albumen may be shown by the addition of nitric acid, or by the application of heat.

The urine immediately on its discharge is turbid, but on being allowed to rest, the pus separates in a clearly defined layer at the bottom; on shaking, it easily mixes again with the urine, and if that fluid have an alkaline reaction the pus becomes tough and fibrous. Pus-corpuscles may be detected by the microscope, and if the urine has an alkaline reaction, they will be mixed with crystals of the ammoniaco-magnesian phosphate and with an amorphous precipitate of phosphate of lime.

In order to determine with certainty whether a urinary sediment consists of mucus or of pus, urine which has been just discharged should be examined: the rapid descent of the pus-corpuscles from urine which is turbid at the period of its discharge, and the formation of a sediment which is frequently discoloured, or mixed with blood, together with the presence of a considerable amount of albumen in the urine, leave no doubt respecting the diagnosis. (See page 447.)

Diabetes mellitus.

In diabetes mellitus it is well known that the urine undergoes a very peculiar change; it contains a certain quantity of sugar, which in its ultimate constitution is perfectly identical with grape-sugar, and in consequence of which the urine possesses the property of deflecting the polarized ray to the right. Diabetic urine differs moreover in its physical relations from the normal secretion; it is paler, has a turbid wheyish appearance with a greenish tinge, and a higher specific gravity,—according to Willis, from 1025 to 1055.

Henry drew up a table for the determination of the solid constituents of diabetic urine by the mere application of the urinometer. The results, as far as my experience goes, come sufficiently near to the truth to give fair approximate values to the solid residue from the specific gravity. G. O. Rees recommends the table, having confirmed it by his own experiments; I have somewhat extended its limits, and shall give it here.

Spec. grav. at 60°.	Solid residue in 1000 parts.	Spec. grav. at 60°.	Solid residue in 1000 parts.
1005	11.7	1012	29.2
1006	14.2	1013	31.7
1007	16.7	1014	34.2
1008	19.2	1015	36.7
1009	21.7	1016	39.2
1010	24.2	1017	41.7
1011	26.7	1018	44.2

1019	46·7	1035	86·4
1020	49·2	1036	88·8
1021	51·6	1037	91·3
1022	54·1	1038	93·8
1023	56·7	1039	96·3
1024	59·1	1040	98·7
1025	61·6	1041	101·2
1026	64·0	1042	103·7
1027	66·5	1043	106·2
1028	69·1	1044	108·7
1029	71·5	1045	111·1
1030	73·9	1046	113·6
1031	76·4	1047	116·1
1032	78·8	1048	118·7
1033	81·4	1049	121·2
1034	83·9	1050	123·6

[In my paper¹ on the specific gravity of the urine in health and disease (founded on 200 observations,) I have shown that Christison's formula, $\Delta \times 2\cdot33$, gives more correct results than the above table. Δ indicates the excess of the specific gravity over 1000. Thus, supposing it is desired to ascertain the amount of solid matter in 1000 parts of urine whose specific gravity is 1035, Δ is here represented by 35, and $35 \times 2\cdot33 = 81\cdot55$, the required number.]

According to Schönlein there is no sugar in the urine in the first stages of the disease, but albumen; and as the albumen subsequently disappears, the formation of sugar in the urine commences.

The quantity of urine increases in an extraordinary degree. P. Frank mentions a case in which fifty-two pounds were discharged during twenty-four hours. According to Bouchardat, the average quantity discharged in the course of the day amounts to from ten to seventeen pounds.

Opinions regarding the composition of the urine are very contradictory, and sufficient analyses have not yet been instituted to enable us to regard any one view as positively correct. Some assert that as the sugar increases in the urine the urea and uric acid decrease, while others maintain that although the absolute quantity of urea in a given amount of urine is actually diminished, yet that on account of the large quantity of urine discharged, the amount of urea is not less than, and in fact exceeds the normal average.

Thus M'Gregor shows that the urine of twenty-four hours in one case of diabetes contained 1013 grains of urea; in another case he found 945 grains, in a third 810 grains, and in a fourth 512 grains, whereas, according to the same authority, the quantity excreted by a healthy person in twenty-four hours does not exceed from 362 to 428 grains. Kane also found in diabetic urine as large a proportion of urea as in the normal secretion. My own analyses certainly tend to show that the ratio of urea to the solid residue is always much less than in health, and that this ratio is diminished in proportion to the increase in the quantity of the sugar: bearing in mind, however, the increased secretion of urine, it is very possible that in some cases the urea is

¹ Lancet, June 15, 1844.

not absolutely diminished: the apparent connexion between the urea and the sugar may then be simply explained by the mere increase of the sugar, which, by increasing the solid residue, causes a relative diminution of the urea.¹ The same is probably the case with respect to the uric acid; when no crystals of uric acid are separated after the addition of free hydrochloric or nitric acid to diabetic urine, the cause may lie in the proportion of water being so large as to retain the uric acid in solution. I have frequently observed this to be the case, for on the addition of free hydrochloric acid to the urine no uric acid has been separated, when upon treating that portion of the residue of the urine which is insoluble in alcohol with nitric acid, I have always obtained the red colour which is characteristic of uric acid. Becquerel, however, has observed a spontaneous sediment of uric acid thrown down by diabetic urine.

[In this country a sediment of uric acid is by no means rare; I have observed it in at least six cases, usually in the form of bright yellow lancet-shaped crystals.]

I have observed cases in which I have convinced myself that the absolute quantity of urea was diminished.

A man aged 52 years, treated for diabetes mellitus in our hospital did not pass more than from two to two and a half quarts of urine in the twenty-four hours. In its external appearance it was perfectly normal; it contained, however, 8·6% of sugar, and only 0·026% of urea, so that while a healthy man excretes about an ounce of urea in the twenty-four hours, in this case there were only thirteen grains excreted in an equal time. In another man who was being treated by Dr. Lehwers, and who indulged freely in sugared drinks, the quantity of urine in twenty-four hours amounted to between four and five quarts, and contained mere traces of urea. The urine was very pale and turbid, its specific gravity was only 1018, and it contained 4·2% of solid residue, 3·9 of which were sugar. After the discontinuance of the sugar, and the adoption of a proper diet, the specific gravity became lower and the urine contained as much urea as constituted a fifth part of the solid residue: the sugar had also decreased to one half its original amount. Subsequently the sugar almost entirely disappeared from the urine; the urea, on the other hand, had increased to such an extent as to constitute a third part of the solid residue.

Bostock is of opinion that diabetes mellitus is not unfrequently preceded by a diseased condition, (in fact a kind of diabetes,) during which a large quantity of urine very rich in urea is excreted. As

¹ In connexion with this subject, we may refer to the experiments of Henry. On mixing the residue of six quarts of diabetic urine with the residue of one quart of healthy urine, and adding nitric acid, only a small quantity of nitrate of urea was obtained after the mixture had stood for twenty-four hours; and on mixing the residue of eight quarts of diabetic urine with that of one quart of healthy urine, and treating it in a similar manner, not a crystal of nitrate of urea could be observed after it had stood for forty-eight hours. Hence it is indispensably requisite that the sugar should be first removed (as completely as possible) before we attempt to determine the urea.

the diabetes becomes developed the urea gradually diminishes as the sugar increases.

Willis¹ states that the urine is occasionally rather turbid on emission, and has then been found to contain a quantity of albuminous matter in the caseous form.

According to Schönlein the urine during the early stage of diabetes contains albumen, and in proportion to its increase the urea diminishes: in the second stage the albumen disappears either totally or partially, and sugar takes its place. I have only detected albumen in two cases of diabetic urine, viz., in the case to which I have already referred, in which I analyzed the urine at a time when the patient took a good deal of sugar in his drink; in this case, however, the disease had made considerable progress: and in the urine of a girl a few days before her death; in this instance it existed in considerable quantity, amounting to 0·2% of the urine, or 3·7% of the solid residue.

Brett² found casein and butter in a case of diabetic urine.

Diabetic urine sometimes contains an insipid species of sugar, which, however, according to Bouchardat,³ corresponds in all other properties with the ordinary sweet diabetic sugar, possessing the capability of fermenting, and being convertible by acids into sweet sugar. I have had only one opportunity of observing sugar of this nature.

A girl with diabetes mellitus discharged an abundant quantity of very saccharine urine, and the sugar which was obtained from it had all the properties of grape-sugar. Subsequently the strength of the patient, which had been long giving way, decreased to such an alarming extent as to cause apprehensions of her speedy dissolution. Two days before her death the urine was again sent to me for examination; and I was not a little surprised to find in it a perfectly tasteless sugar soluble in hot spirit, and mixed with a considerable quantity of a gummy matter insoluble in spirit, which, on the application of heat, emitted a peculiar odour not unlike that of burned paper.

The salts in diabetic urine are stated by Gueudeville, Bostock, and Henry, to be diminished, while they retain their normal proportion to each other. I have found the amount of earthy phosphates not much below the normal average.

Lehmann⁴ was the first who directed attention to the occurrence of hippuric acid in diabetic urine: it has since been detected by Ambrosiani, Müller, and very recently by myself. I obtained it in the same manner as Lehmann did, from the ethereal solution of the dried residue: after evaporation there remained a slight brownish-yellow residue, in which, with the help of the microscope, I observed heaps of long acicular crystals. The residue was warmed with a few drops of a weak solution of potash, which neutralized the acid reaction, and the solution was then filtered. On the addition of a solution of per-

¹ Urinary Diseases and their Treatment, p. 200. ² London Medical Gazette, July, 1836.
³ Revue Médicale, 1839. ⁴ Journ. für prakt. Chem. vol. 6, p. 114.

chloride of iron a cinnamon-yellow precipitate was obtained, which on being warmed contracted itself into red flocculi.

On allowing diabetic urine to stand for a considerable time, a sediment forms, which consists for the most part of fermentation-globules. If the urine above this sediment is allowed to remain for some time longer at a suitable temperature, it begins to undergo fermentation. I have frequently observed the fermentation-globules, and have represented them in fig. 35.

I have made several minute analyses of the urine in diabetes mellitus. The three following analyses were made with the urine of a man aged 50, to whose case reference has been previously made. The first analysis was made at a time when the patient indulged freely in sugared drinks. The urine then contained a mere trace of urea. After the patient had been properly dieted for some time, I obtained the urine for the second analysis, which in its results differs very little from the first. Eight days from this time I again analyzed it, and found that the sugar had almost entirely disappeared.

About three months afterwards I received some more of his urine for analysis; it was then very rich in sugar, while urea was present to only a very small amount. Albumen was only detected in the urine of the first analysis. Uric acid was always present, but only in very small quantity.

			Anal. 129.	Anal. 130.	Anal. 131.
Specific gravity	-	-	1018-00	1016-00	1007-00
Water	-	-	957-00	960-00	989-00
Solid constituents	-	-	43-00	40-00	18-00
Urea	-	-	traces	7-99	4-63
Uric acid	-	-	traces	a trace	a trace
Sugar	-	-	39-80	25-00	a trace
Extractive matter and salts	-	-	2-10	6-50	8-60
Earthy phosphates	-	-	0-52	0-80	1-00
Albumen	-	-	was present.		

The urine of the first two analyses was of a pale-yellow colour, and slightly acid; in the third case it was as clear as water, and produced no change on test paper.

The two following analyses were made with the urine of a girl aged 20 years, who was being treated for diabetes mellitus in Prof. Wolff's clinical wards.

The first analysis was made eight weeks before the second; I made an analysis of the blood at the same time. (See Analysis 42, page 267.)

The second analysis was made two days before death; it revealed the fact that the diabetes sapidus had changed into diabetes insipidus; moreover, at this period, the urine contained a considerable quantity of albumen.

			Analysis 132.	Analysis 133.
Specific gravity	-	-	1032-00	1021-00
Water	-	-	921-65	947-20
Solid constituents	-	-	78-15	52-80
Urea	-	-	0-54	1-47
Sweet sugar	-	-	72-00	—
Insipid sugar	-	-	—	27-61

Extractive matter and salts -	-	-	4.20	2.80
Earthy phosphates -	-	-	0.92	0.40
Albumen -	-	-	-	2.00
Gummy matter -	-	-	-	17.30

Analysis 134 was made with the urine of a man aged 52 years, who was being treated in Schönlein's clinical wards for diabetes. The urine was not passed in very large quantity, but it contained a remarkably large proportion of sugar. The composition of the blood, which also contained sugar, is given in Analysis 41, page 267.

	Analysis 134.
Specific gravity -	1036.00
Water -	909.60
Solid constituents -	90.40
Urea -	0.26
Uric acid -	a trace
Sugar -	86.30
Extractive matter and salts -	2.10
Earthy phosphates -	1.50

I have recently had an opportunity of making a careful examination of the excretions of a diabetic patient. He was a man aged 40 years, who had suffered from intense thirst and had observed a great increase in the amount of his urine for the preceding ten months. At the period of his admission into the hospital, the colour of his urine was normal, and an acid reaction always observed, which, however, became more decided some time after emission: in the course of ten or twelve hours it usually became turbid, and deposited a light viscid sediment consisting of amorphous urate of ammonia and mucus-corpuscles; on two occasions (during the use of a very animal diet) crystals of uric acid were noticed in the sediment. During the period of my investigations I never detected albumen in the urine. The specific gravity varied from 1039 to 1030. It was highest at the commencement of the treatment.

On admission the daily amount of urine averaged nearly five quarts, but while under treatment it was reduced to three quarts. The daily amount of sugar gradually diminished to one third, but was never so thoroughly reduced as to afford hopes of a permanent cure. The daily excretion of urea was at first much diminished, but subsequently reached the healthy average. Uric acid was always present, but not in so considerable a quantity as would have been found in the urine of healthy persons living on a similar diet. The amount of fixed salts varied considerably, but was always larger than in a state of health.

After the use of the ordinary hospital diet for a few days, he was placed on a very nitrogenous diet, consisting of beef-tea, eggs, meat, milk, and white bread. Subsequently coffee was substituted for the milk, and the amount of bread diminished. And still later, gluten-bread containing only one-half the amount of starch, but three times the amount of nitrogenous matter, was given in its place.

During his last three weeks he consumed daily, one pound of gluten-bread, two of beef from which a quart of beef-tea had been made, besides a quarter of a pound of ordinary boiled beef, three or

four ounces of roast veal, six eggs, and two quarts of coffee prepared from an ounce of the beans. Although this quantity was (according to his own statement) sufficient to satisfy his hunger, he was occasionally detected in appropriating the farinaceous diet of other patients. With regard to medical treatment, opium and its various compounds were first given; he was then treated with astringents, the nitrogenous diet being at the same time increased, and the saccharine and farinaceous matters diminished. After this course had been pursued for some time without any decided benefit, he took daily two ounces of cod-liver oil, and after this had been continued for twelve days, he took, additionally, four grains of iodide of iron. Finally, (these medicines being continued) the gluten bread was ordered, and the milk and white bread stopped. Under this treatment the daily amount of sugar fell from twelve ounces to seven and three-quarters; it subsequently, however, rose to nine ounces and one drachm. The urea, which on his admission amounted to only three drachms in twenty-four hours, was now increased to one ounce and three drachms, and the uric acid rose from a mere trace to twelve grains.

During this course of treatment the digestion seemed good, the thirst diminished, and he occasionally perspired considerably; he had become, however, very emaciated. The saliva was slightly alkaline, and I examined it for sugar unsuccessfully. Sugar was, however, detected in the perspiration. The analysis of his faeces will be found in Chapter X.

In the determination of the sugar and urea there are certain difficulties which I shall briefly notice. On treating diabetic urine evaporated to the thickness of a syrup with warm spirit, the mucus, uric acid or urates, and earthy phosphates are precipitated. On evaporating the filtered spirituous solution to the consistence of a thin syrup, and adding anhydrous alcohol, an insoluble semifluid mass separates, which, when repeatedly treated with anhydrous alcohol, becomes finally thick and tough. On dissolving this saccharine mass in warm spirit, and again precipitating it by anhydrous alcohol, it will still be found to contain a certain amount of urea; in fact, I have detected urea after the operation has thrice been effected, and I find that sugar can only be obtained free from urea by allowing it to crystallize spontaneously from its spirituous solution. In consequence of the difficulty of separating these substances, I proceed in the following manner: the solid residue of the urine is first accurately determined; a weighed portion of urine is then evaporated, mixed with spirit, and the solution filtered. The filtered solution is evaporated to the consistence of a syrup, and, when cold, mixed with a sufficient quantity of concentrated nitric acid to allow of a few drops remaining on the surface of the crystalline mass. It must then be submitted to a low temperature, and the crystals placed on blotting paper and compressed till they cease to communicate moisture. The fixed salts must be determined from a separate portion of urine. If we deduct from the known quantity of solid residue the portion insoluble in spirit

(from which the uric acid is determined,) the urea, and the fixed salts, we obtain, as the difference, sugar and alcohol-extract which appears to decrease in diabetic urine in proportion as the sugar increases. The following are the special results of my analyses of the urine of this man.

No. 135 represents the analysis of the urine before the commencement of the animal diet; No. 136, shortly after its commencement; No. 137, during the same diet, shortly before the use of the cod-liver oil; No. 138, after the oil had been taken for eight days; No. 139, after the iodide of iron had been used for eight days; No. 140, after the gluten-bread had been tried for eight days; No. 141, two days subsequently to the preceding analysis, there being a considerable increase in the secretion.

In twenty-four hours there were discharged:

	Anal. 135.	Anal. 136.	Anal. 137.
Specific gravity	4½ quarts	3 quarts	4 quarts
Solid constituents	1037·1	1038·9	1029·7
Sugar and extractive matter	14·5 oz.	9·9 oz.	10·0 oz.
Urea	12·5 "	7·5 "	8·5 "
Uric acid	3 drachms	5 drachms	7 drachms
Fixed salts	—	5 grains	8 grains
	—	—	6 drachms
Anal. 138.	Anal. 139.	Anal. 140.	Anal. 141.
Specific gravity	4 quarts	4 quarts	3½ quarts
Solid constituents	1030·2	1030·4	1032·37
Sugar and extractive matter	10·5 oz.	10·5 oz.	10·2 oz.
Urea	8·9 "	7·25 "	8·1 "
Uric acid	7·8 drs.	10·0 drs.	1·1 "
Fixed salts	10 grs.	—	5 grs.
	6 drs.	8 drs.	15 grs.
			1 oz. 9 grs.

The composition of the urine appears from my observations to undergo a rapid modification as soon as there are decided indications of convalescence. The sugar decreases to a very great extent, and is replaced by albumen, a substance of frequent occurrence at the commencement of the disease, and apparently alternating with the sugar.

When the sugar is no longer perceptible to the taste (either in the urine or in the spirit-extract,) it can always be readily detected by Trommer's test. I usually take a test-tube of about seven inches in length, fill three fourths of an inch of it with urine, and heat it with 3ss or 3ij of carbonate of potash; I add five or six times the volume of spirit of ·845, and again boil; a few drops of a solution of sulphate of copper are then added, and heat again applied. If much sugar is present, the reduction of the oxide of copper to a state of sub-oxide occurs very quickly in the lower stratum of solution of carbonate of potash, and the fluid becomes of a yellow, red, or copper colour; if the quantity of sugar is very small, the reduction still takes place, but much more gradually. If, however, no sugar is present, the solution of potash remains of a blue or bluish-green colour.

I have recently analyzed a specimen of diabetic urine containing only a very small amount of sugar, although previously that consti-

tuent had been present in large quantity. A short time previously to the last analysis, no sugar could be detected, but albumen was present. The urine passed at different periods of the day was analyzed separately. The quantity of urine passed between noon and evening contained most sugar, and was most abundant; that passed during the night contained the least. The three analyses gave the following results:

	Anal. 142. Urine from Noon till Evening.	Anal. 143. Urine during the Night.	Anal. 144. Urine from early Morning to Noon.
Quantity of urine	34.3 oz.	6 oz.	10.7 oz.
Specific gravity	1026.02	1024.38	1027.76

In 1000 parts there were contained:

Water	943.00	946.43	934.47
Solid constituents	57.00	53.57	65.53
Urea	14.12	17.60	16.21
Uric acid	0.34	0.80	0.50
Chloride of sodium, with a little carbonate and sulphate of soda	11.27	8.60	10.50
Alkaline sulphates and phosphates	5.80	4.65	5.70
Earthy phosphates	1.20	0.80	0.90
Extractive matters, with am- monia-salts and traces of sugar	24.51	21.94	39.18

The whole amount of the different constituents discharged in twenty-four hours was as follows:

Solid constituents	-	-	-	-	3 oz.
Urea	-	-	-	-	365 grs.
Uric acid	-	-	-	-	11.2 grs.
Fixed salts	-	-	-	-	425 grs.
Extractive matters	-	-	-	-	1 oz. 139 grs.

[The following analysis of diabetic urine has been made by Dr. Reich.¹ The particulars of the case are not recorded:

Water	-	-	-	-	907.88
Solid constituents	-	-	-	-	98.12
Urea	-	-	-	-	8.27
Hippuric acid	-	-	-	-	0.04
Sugar	-	-	-	-	56.00
Water-extract	-	-	-	-	5.60
Alcohol-extract	-	-	-	-	16.36
Mucus	-	-	-	-	0.54
Albumen	-	-	-	-	0.58
Chloride of potassium	-	-	-	-	0.30
Chloride of sodium	-	-	-	-	0.84
Chloride of ammonium	-	-	-	-	0.66
Sulphate of potash	-	-	-	-	0.26
Phosphate of soda	-	-	-	-	2.15
Phosphate of lime	-	-	-	-	0.46
Silica	-	-	-	-	0.66

The hippuric acid was determined by evaporating the urine to one eighth of its volume and treating it with hydrochloric acid, when that constituent was thrown down as a white deposit.

An instance in which diabetic urine occurred in a state of extraor-

¹ Simon's Beiträge, p. 545.

dinary concentration has been observed by Bouchardat. Its composition is given below. The three other analyses were made by Dr. Percy; the cases are fully recorded in the London Medical Gazette for 1844.

	Bouchardat.	Spec. grav.	1042-00	1035-00	Percy.
Water -	837-58	894-50	918-30	898-90	
Solid constituents	162-42	105-50	81-70	101-10	
Urea	8-27	12-16	30-32	2-39	
Uric acid	-	0-16	0-26	not isolated	
Sugar	134-42	40-12	17-15	79-10	
Extractive matters and salts	20-34 }		32-59	19-52	
Earthy phosphates	0-38 }	53-06	1-30	0-09]	

Lehmann¹ has made two minute analyses of diabetic urine; he found neither albumen, urea, nor uric acid in it, but a considerable amount of hippuric acid. The urine of a man aged 18 years had a specific gravity of 1029-5, was pale, when fresh, had a milky smell, and subsequently became acid. The solid constituents amounted to 62-05, of which 58-15 were sugar. Ether took up 0-187, which was chiefly hippuric acid. The urine of a man aged 38 years was turbid, of a straw colour, contained neither albumen, urea, nor uric acid, had a specific gravity of 1028-5, and contained 56-24 of solid constituents, of which 50-9 were sugar. There were also found 0-31 of hippuric acid, 0-169 of salts soluble in alcohol, 0-21 of water-extract, 0-39 of salts soluble in water, 0-31 of salts insoluble in water, and 0-23 of mucus.

An interesting case of diabetes in a girl aged 8 years was observed by Cantin.² The urine which she discharged was of a blue colour, and impregnated with sugar. The colouring matter appeared to possess the properties of Prussian blue.

Diabetic urine has been observed in children as well as in adults, and during the period of puberty.

The female sex is not exempt from this disease.

It is impossible in the present state of our knowledge on this subject to state with certainty in what part of the system the sugar is formed, which is produced and excreted in such extraordinary quantity. It is either directly formed in the chylopoietic system or it is produced in the peripheral vascular system, or it is generated by a morbid action of the cells of the kidney, or finally its origin may be due to a combination of these agencies.

To decide this point satisfactorily, (and for the science of medicine it is most important that it should be decided,) the following points should first be established by experiments on a sound and certain basis:

(1.) Is the correspondence of the absolute diminution of the urea with the absolute increase of the sugar, an invariable rule?

(2.) May not the nitrogen be removed from the system in some other way, probably in the form of ammonia-compounds?

¹ De diabetica urina. Dissert. inaug.

² Journ. de Chim. Méd. vol. 9, p. 104.

- (3.) Do the other secretions undergo a change, especially the bile?
- (4.) Does the air which is exhaled from the lungs differ in its composition from that which is expired by healthy persons?
- (5.) Do the kidneys, liver, or lungs undergo any changes? and if so, what are their nature?

If the connexion between the appearance of the sugar and the diminution of the urea is constant, that is to say, if, without exception, the urea invariably decreases in the same ratio as the sugar increases, then we must assume with Berzelius, that in place of the metamorphosis of the protein-compounds into urea which occurs as a normal process, these compounds are in this case, from certain causes which are unknown to us, transformed into sugar, ammonia, and perhaps into nitrogenous extractive matters. This hypothesis is, however, opposed by the facts which were observed by M'Gregor: in his cases the daily secretion of urea equalled, and in fact exceeded the healthy average.

It has been established by the researches of Rollo, Bouchardat, myself, and others, that the blood really contains sugar. It exists, however, in an extremely minute quantity, and my own observation confirms the remark of Bouchardat, that it is most abundant a short time after meals: the blood of a girl in whom the disease had made considerable progress, when taken before a meal, exhibited a mere trace of sugar. Hence we are led to infer that the formation of sugar occurs in the chylopoietic viscera alone, or there and in the blood simultaneously.

From experiments made by M'Gregor,¹ he infers that the sugar is formed in the stomach alone. After having convinced himself of the existence of sugar in diabetic blood by having induced fermentation, he sought for, and found it in the matters vomited both by a healthy man and a diabetic patient, three hours after dinner. Upon treating the healthy man and the diabetic patient with an initiatory course of emetics and purgatives, and then for three days feeding them with nothing but beef and water, no sugar was found in the matter vomited by the healthy man, whilst there was still sugar in the other case. M'Gregor also found sugar in the faeces of diabetic patients: no sugar was, however, found in the sweat. It is well known that persons with this disease do not readily perspire; on the contrary, the skin becomes dry, rough, and peels off. Willis² relates a case of diabetes that fell under his own observation, in which the surfuraceous exfoliation of the cuticle had a decidedly sweet taste.

From pathological anatomy we learn that the kidneys in death from diabetes are very frequently softened, and according to Meyer (who refers the formation of sugar to the kidneys,) even disorganized, their blood-vessels much enlarged, and the substance of the papillæ, and the tubuli very permeable; the kidneys have also been found

swelled, atrophied, suppurating, and containing calculi. The condition in which the liver has been found is also various: the bile is,

however, usually very far from being in a normal condition; it is of a pale yellow colour, very fluid, and, instead of being alkaline, has usually an acid reaction. The veins which form the portal system are overloaded, and the mesenteric vessels are generally congested. As the disease becomes further developed the lungs participate in the general disturbance, for, according to Willis, pulmonary phthisis is the immediate cause of death in two-thirds of the cases of diabetes. Traces of morbid action have also been found in the nervous system.

It is of great importance in reference to the ætiology of diabetes mellitus to ascertain whether the changes which are revealed to us by the prosecution of the morbid anatomy of the disease, are consequences of the disease itself, or whether they had a previous existence in those blood-metamorphosing organs, the kidneys, liver, and lungs, and whether the formation of the sugar is due to them.

The questions which I have already suggested are of much importance in elucidating these points.

Taking into consideration all that is known of the origin of diabetes mellitus, it appears very probable that the sugar is formed not in any single organ, but that it is produced by a diseased condition of the whole system, and we are almost led to adopt the opinion expressed by P. Frank, that a specific influence is exercised upon the nerves of the fauces by a spontaneously generated *virus diabeticum*, which occasions an insatiable desire for drink, and at the same time exerts a peculiar influence upon the nerves of the lymphatic system, exciting them to extraordinary activity.

This activity of the lymphatic system, when associated with an excessive absorption from all the secreting surfaces of the body, causes the premature elimination of raw and unassimilated chyle, which, not being adequate to the formation of blood, must be again removed from it. When we consider what an extraordinary quantity of sugar is carried off, even in those patients who are restricted to animal food, we cannot doubt that the sugar is formed from the protein-compounds,¹ and in all probability, future and more accurate analyses of the urine, the bile, and the expired air, will enable us to understand, in what manner the nitrogen is removed from the system, a point upon which we are at present in the dark. For although we can well conceive the possibility of the protein-compounds being, under peculiar circumstances, resolved into sugar of grapes, and certain nitrogenous compounds similar to protein itself, yet these latter must be capable of being detected.

Periodic symptoms have been occasionally observed in diabetes mellitus.

A physician in Berlin has a patient who, at certain times of the year, had periodical attacks of diabetes mellitus, which after continuing for some time, and with the application of proper diet, would disappear: although the amount of sugar which was excreted during

¹ [Buge's views on this subject may be seen in my Report on the recent progress of Animal Chemistry, in vol. 2 of Ranking's Half-yearly Abstract.]

these attacks was by no means inconsiderable, the patient did not exhibit that meagerness which usually succeeds a prolonged continuance of the disease; on the contrary, he became corpulent, and complained of no disturbance of his general health.

Diabetes insipidus.

Under the term "diabetes insipidus" are included several diseased states, in which the urinary secretion is very much increased, but where the urine contains no sugar, either sweet or insipid, which is capable of fermentation. Willis treats of these different states under the heads Hydruria, Anazoturia, and Azoturia.

Hydruria, which is also known as diuresis, polyuresis, and polydipsia, seems to be capable of continuing sometimes for several years, without being accompanied by any other morbid symptoms than a frequent desire to micturate, and an insatiable thirst. Willis mentions several cases of the kind: amongst others, that of an artisan, 55 years of age, who from his sixteenth year had upon an average drunk nearly two pailsful daily, and who, during the same period, passed on an average thirty-four pounds of urine and one of faeces. The urine was scarcely denser than pure water and contained no sugar.

A similar case is recorded of a woman aged 40 years, who from her infancy experienced constant thirst, and an enormous secretion of urine. She enjoyed good health, and was the mother of several children.

Becquerel observed a case of polydipsia or hydruria in a servant girl aged 23 years. After recovering from an attack of acute nephritis she lapsed into a state of anaemia, for which ferruginous medicines were exhibited, but without success. A continuous state of thirst then came on; so much so, in fact, that she daily took five or six litres of fluid without allaying the sensation. The urine was very pale and greenish, was rather turbid from the presence of mucus, and had an acid reaction. Its specific gravity was 1006, and about six pounds were excreted in the course of the day.

Its composition was as follows :

Water	-	-	-	-	-	989·7
Solid constituents	-	-	-	-	-	10·3
Urea	-	-	-	-	-	3·0
Uric acid	-	-	-	-	-	0·2
Fixed salts	-	-	-	-	-	3·6
Extractive matters	-	-	-	-	-	3·7

[L'Heretier¹ has published an analysis of urine very similar in its character. The patient was a pregnant woman. She discharged about ninety-five ounces daily, and the specific gravity was 1009·4.

It contained in 1000 parts:

Water	-	-	-	-	-	989·7
Solid constituents	-	-	-	-	-	10·3
Urea	-	-	-	-	-	3·3

¹ *Traité de Chim. pathol.* p. 553.

Uric acid	:	:	:	:	:	0·2
Fixed salts	:	:	:	:	:	3·2
Organic matters	:	:	:	:	:	3·6

I am indebted to Dr. Golding Bird for the following analysis of the urine in polydipsia. A woman aged 43 years observed that, in the course of four months, the amount of urine rose from the normal quantity to 140 ounces. The specific gravity was 1010.

The whole quantity of water amounted to	:	:	:	60419 grains
" Solids	:	:	:	1439 "
Urea	:	:	:	376 "
Uric acid	:	:	:	21 "
Fixed salts	:	:	:	462 "

When this diuresis occurs in nervous persons at an advanced age, Willis observes that it should not be regarded lightly, as the prognosis is almost always unfavourable.

By azoturia, Willis understands the excessive secretion of urine very deficient in solid constituents, and especially in urea, and he considers that all the cases of diabetes which have been reported as cured may probably be classed under this head. The urine is passed in very abundant quantity, and is either of a pale straw colour or entirely colourless, and has a very slight odour. It has either a very mild acid, or else a neutral reaction; in the course of twenty-four hours it becomes ammoniacal, and forms a precipitate, at the same time becoming covered with a film containing crystals of ammoniacomagnesian phosphate. This disease seems common among the children of the poor, who have been brought up on an improper diet. In a child treated by Willis the urine was perfectly devoid of colour, its specific gravity was that of distilled water, and 1000 grains left, after evaporation, a residue of scarcely one grain, which consisted of mucus, urate of ammonia, phosphates, and a trace of urea.

A man, who for many years had suffered from a sensation of extreme weakness, thirst, and gnawing pain in the region of the heart, discharged from six to seven quarts of urine daily: it was almost devoid of odour, of a pale straw colour, and one thousand parts left a solid residue of twenty, of which only two were urea.

A case of the same nature was treated by Stosch. A man who complained of pain in the cardiac region, thirst, and weakness, passed from four to six quarts of urine daily; it contained no sugar, and scarcely a trace of urea or of the other ordinary constituents of urine.

By the term azoturia Willis understands that form of disease which is usually known as diabetes insipidus, in which the urine is increased in quantity, is usually transparent and pale, but sometimes deeply coloured, and is peculiarly distinguished by the large amount of urea which it contains. The urine has a slight, but at the same time a urinous odour, an acid reaction, and its specific gravity (1018—1035) is higher than in the preceding form of disease. When the density is considerable, crystals of nitrate of urea are often yielded

on the addition of nitric acid, after a few hours' rest, without any previous concentration.

The general symptoms are the same as in the former varieties: loss of strength, feeling of weakness, gnawing pains in the region of the heart, thirst, &c. An artisan, thirty-seven years of age, (treated by Willis,) contracted the disease in consequence of a cold, and passed a large quantity of pale urine, amounting to about five quarts daily. The specific gravity varied from 1022 to 1028. On the addition of nitric acid to the urine at its highest degree of density, crystallization of nitrate of urea occurred in a few hours. 1000 grains left, on evaporation, 72 of solid residue, of which 51 were composed of urea, alcohol-extract, and salts soluble in alcohol; 14 were hydrochlorates and sulphates; 6 were earthy salts, especially phosphates; and 1 grain consisted of mucus. Willis is of opinion that this form of diabetes frequently precedes diabetes mellitus, or alternates with albuminous or saccharine urine.

[Dr. Golding Bird analyzed the urine of a fine but emaciated man aged 35 years, who stated that his brother had died of diabetes. The urine in twenty-four hours amounted to 50 fluid ounces, and had a specific gravity of 1030.

The water amounted to	-	-	-	-	20956	grains
Solids	-	-	-	-	1574	"
Urea	-	-	-	-	757.95	"
Uric acid	-	-	-	-	6.75	"]

In diabetes chylosus the urine contains a very large quantity of albumen and fat, so as to give it almost a milky appearance. I have already alluded in general terms to this form of urine, and I have only further to add that, according to Chevallier, it comes on after the use of mercury, and, associated with haematuria, is endemic in the Isle of France; it has also been several times observed in Europe.

Willis remarks that these disturbances in the renal secretion frequently occur without causing any degree of constitutional disease, and often without any detriment whatever to the general health. Slightly removed from this form of urine, is that in which a protein-compound approximating to a modification of casein, or where actual milk (milk-metastasis,) is discharged with the urine.

We have lastly to mention a form of chylous urine in which fibrin and albumen, but no blood-corpuscles, are discharged.

Abernethy observed urine of this sort in a woman, and Prout has described several cases. It coagulates spontaneously, and forms a mass which, as Abernethy remarks, might be served up at table for blanc-mange.

Dropsy.

During dropsical affections the urine often differs considerably from its normal state. Its quantity is generally less than in a state of health, and it presents various peculiarities in quality. It is some-

times dark, very acid, rich in uric acid, and, according to Schönlein, in urea also; sometimes it contains blood; in other cases it is pale and opalescent, resembling anaemic urine, and not unfrequently containing a considerable amount of albumen; but this substance is by no means invariably present in the urine of dropsy.

In hydrothorax the urine, according to Schönlein, is secreted scantily; it is of a dark purple red colour, and presents a fiery appearance; during the approach of recovery it becomes more abundant, and, especially when the disease is complicated with inflammation of the pleura or lung, throws down precipitates of a reddish-yellow or brick-dust colour, which are frequently mixed with purulent mucus.

In chronic hydrothorax, a thick, fiery-red urine is generally passed, which speedily deposits a considerable sediment of a brick-dust or rose-red colour; in some few cases a clear, transparent urine, like that which is passed in spasm, is discharged in tolerable abundance.

I have analyzed the urine of a man who was suffering both from hydrothorax and cavities in the lungs. It was deeply coloured, had a strong acid reaction, contained no albumen, and formed a slight sediment of urate of ammonia.

Its specific gravity was 1025. Its composition was as follows:

	Analysis 145.
Water	936·54
Solid constituents	63·46
Urea	22·17
Uric acid	0·53
Fixed salts	12·60
Earthy phosphates	0·36
Extractive matter	26·80

In ascites inflammatorius the urine is secreted in diminished quantity, is of a dark red or brownish colour, and not unfrequently contains blood in a state of solution, or blood-corpuscles; the latter may be recognised by the microscope, and if the urine is allowed to stand, they form a red sediment; frequently, however, no haemato-globulin, but merely albumen, is present. On the approach of recovery, there is, according to Schönlein, a copious discharge of urine, accompanied by a purulent, and subsequently a mucous sediment.

At the commencement of chronic ascites the urine is not much diminished in quantity; it assumes a pale or opalescent shining green colour, and contains a large quantity of albumen and mucus.

Persons suffering from periodic ascites pass a small quantity of red, turbid urine, which sometimes deposits very copious sediments of uric acid and urate of ammonia. Towards convalescence, the discharge of urine becomes very abundant, and it continues to throw down copious lateritious sediments. The occurrence of a clear, slightly coloured, spastic urine, without these critical sediments, must be regarded as an unfavourable symptom, since it indicates renal "colliquation." (Schönlein.)

In those varieties of ascites that arise from affections of the liver, spleen, stomach, and generative organs, the amount of urine is also

diminished. It appears either of a dark red or brown colour without sediments, (as when the ascites arises from disorganization of the female generative organs, or of the pancreas,) or it throws down copious lateritious or fawn-coloured sediments, (as in diseases of the liver, spleen, or vena portæ;) sometimes it is coloured with bile, as in jaundice. (Schönlein.)

Becquerel likewise observed that the urine in ascites arising from disease of the liver, is scanty, highly coloured, and almost always throws down a dark or reddish sediment of uric acid.

In dropsy from disease of the heart the urine, according to Becquerel, assumes various phases; it may be pale or highly coloured, clear or turbid, with or without sediments, and may or may not contain albumen. He also observes that in the advanced stage of hypertrophy of the heart there is a state of hyperæmia induced in some other organs, especially a good deal of congestion of the kidneys, much as occurs in the first stage of Bright's disease, which causes a change in the elimination of the urine from the blood, and accounts for the transitory presence of albumen, the same as we observe in severe inflammatory affections.

When the dropsical symptoms are consequent upon disease of the heart alone, the urine, according to Becquerel, is not so much changed as when hepatic disease, (especially cirrhosis,) is associated with it: it is then scanty, deeply coloured, and often reddish, very acid, of high specific gravity (1025—1029,) and usually throws down a copious reddish sediment of uric acid and urate of ammonia.

When the dropsy arises from the combined influence of an affection of the heart and Bright's disease, the urine ordinarily assumes the special characters of the latter disorder, which have been already described. If, however, the disease of the heart causes much functional disturbance, the urine becomes deeply coloured, more acid, and deposits a sediment.

When the dropsy arises solely from disease of the kidneys, the urine is always albuminous: the majority of these cases fall under Bright's disease, which has been already noticed. I examined the urine of a young man 22 years of age, in a far advanced stage of ascites, and whose subsequent dissection revealed suppuration of the kidneys. The urine was pale, turbid, slightly acid, contained much albumen, and deposited a sediment, which was shown by the microscope to consist of pus- and mucus-corpuscles: its specific gravity was 1026.

It contained:

	Analysis 146.
Water	93550
Solid constituents	6450
Urea	1820
Uric acid	110
Albumen and pus-corpuscles	1860
Alcohol-extract with ammonia and lactic acid	1235
Water-extract	460
Fixed salts from the extractive matters	620

The amount of urea was much diminished, being only 27 $\frac{1}{2}$ of the solid residue, whereas the normal average is 39 $\frac{1}{2}$.

On the other hand I found a very appreciable quantity of urea in the dropsical fluid, obtained by puncturing the abdominal parietes.

Nysten analyzed the urine of a man aged 18 years, who had been suffering from ascites for several months. There were only 8 ounces of urine excreted in twenty-four hours; it was turbid and of a reddish colour, very frothy, and when allowed to stand, deposited a white flocculent sediment. It had an ammoniacal odour, a strong alkaline reaction, and contained hardly a trace of urea; but a considerable quantity of colouring matter and albumen were found in it, and more salts than in healthy urine of digestion.

Graves also observed a considerable quantity of carbonate of ammonia in the urine of a labourer who was suffering from ascites, anasarca, and a tympanitic condition of the intestinal canal, urea being almost entirely absent.

In a case of ascites arising from peritonitis, which was only fully recognised on dissection by the changed condition of the peritoneal surface, a small quantity of urine was discharged, which was of a dark colour, and on cooling threw down a considerable lateritious sediment.

[Heller¹ analyzed the urine of a woman aged 40 years, suffering from ascites. The secretion was tolerably copious, of a light yellow colour, and turbid from containing a large quantity of mucus. It was neutral, but speedily became alkaline. Its specific gravity was 1007, and it contained in 1000 parts:

Water	-	-	-	-	-	978·40
Solid constituents	-	-	-	-	-	21·60
Urea	-	-	-	-	-	8·40
Uric acid	-	-	-	-	-	mere traces.
Extractive matter and traces of albumen	-	-	-	-	-	7·11
Fixed salts, chiefly chloride of sodium	-	-	-	-	-	6·00]

In anasarca the properties of the urine appear to vary; it frequently contains albumen in abundance,² while on other occasions there is not a trace of it.

Becquerel relates the case of a girl 9 years of age, who, after being exposed to a sudden and violent chill, was attacked with anasarca on the following day. The skin was hot, and the pulse feverish; after a short time peritoneal effusion came on, but the urine contained no trace of albumen. It was deeply coloured, of high specific gravity, and frequently deposited a uric-acid sediment.

In five cases in which anasarca succeeded general debility (dropsy from anaemia,) Becquerel found the urine very pale, of low specific

¹ Archiv für phys. and pathol. Chemie, vol. 1, p. 47.

² Rayer, Bright, and Christison are of opinion that when albuminous urine occurs with anasarca, it is a certain indication of incipient organic change in the kidney, while on the other hand Blackall and Graves regard the appearance of albumen as a consequence of a general inflammatory diathesis. Becquerel adopts an intermediate view; he attributes the appearance of albumen in the urine in inflammatory affections to a transitory congestion of the cortical substance, similar to that which is found in the first stage of Bright's disease.

gravity (from 1009 to 1012,) and of a greenish tint. In one case he found a little albumen.

Graves¹ relates a case in which a labourer, after getting chilled, suffered much from fever and anasarca. The urine was pale, straw-coloured, very ammoniacal, and formed a sediment of earthy phosphates; it contained scarcely a trace of albumen. Willis, on the contrary, with hardly an exception, found the urine albuminous when the anasarca arose from cold.

[Scherer² examined the urine of a man with anasarca succeeding a severe attack of broncho-pneumonia, from which he was recovering. The urine contained blood. After taking *inf. senegæ* for four days, the hæmaturia ceased. The secretion was then analyzed; its specific gravity was 1022; and it contained in 1000 parts:

Water	-	-	-	-	966·2
Solid constituents	-	-	-	-	33·8
Urea	-	-	-	-	18·5
Uric acid	-	-	-	-	0·9
Lactic and extractive matter	-	-	-	-	6·4
Soluble salts	-	-	-	-	5·2
Earthy phosphates and mucus	-	-	-	-	1·8]

In our observations on scarlatina we remarked that in the anasarca which so frequently succeeds that disease, the urine sometimes contains albumen, and sometimes is free from it.

In ovarian dropsy the urine, according to Schönlein, is very scanty; it contains a large quantity of albumen, which increases in amount as the disease advances.

Jaundice.

In jaundice, whether it be idiopathic or symptomatic, the urine contains bile-pigment, which shows itself in the peculiar colour which it communicates to that fluid. But it sometimes also contains other constituents of the bile, for I have detected biliary resin in icteric urine, and Gmelin found cholesterol in a case in which the flow of bile was impeded.

The colour of icteric urine may vary from a saffron-yellow to a yellowish-brown, brownish-red, or blackish-brown; if there is any doubt whether the colour is produced by biliphaein, we must adopt the steps described in page 439, which will readily determine the point. The presence of bilifellinic acid may sometimes be detected by the taste, and always by the directions given in page 439.

The specific gravity of icteric urine is variable: it depends, (as do the proportions of the ordinary normal constituents,) upon the relative state of the organism, upon other complicating diseases, and upon the absence, presence, or degree of vascular disturbance.

In acute icterus accompanied by fever, Schönlein found the urine at first of a dark red or brown colour from the presence of bile-pig-

¹ Urinary Diseases and their Treatment, by R. Willis, M.D., p. 126.

² Untersuchungen, &c., p. 48.

ment; it afterward became gradually darker, and at last as black as ink.

It continued, however, transparent, and did not form sediments till the crisis.

A servant girl in our hospital aged about 20 or more years presented a case of inflammatory icterus. The skin was of a brown-yellow colour, the tinge on the face and breast being particularly dark; the pulse was feverish, especially towards the evening; the mental faculties disturbed and delirium during the night.

The urine was of a brown, almost a blood-red colour, (thin strata appearing of a deep saffron tint,) it had a powerful acid reaction, and deposited a very abundant brownish-yellow sediment, which consisted partly of crystallized uric acid coloured by biliphaein, and partly of urate of ammonia coloured in a similar manner. The specific gravity of this urine was 1020. It contained:

	Analysis 147.
Water	954-50
Solid constituents	45-50
Urea	12-34
Uric acid with biliphaein	2-90
Alcohol-extract	4-35
Spirit-extract	5-29
Water-extract, mucus, and bile pigment	5-14
Biliary resin	1-45
Biliverdin	1-08
Earthy phosphates	3-14
Chloride of sodium and lactate of soda	2-61
Alkaline sulphates and phosphates with } traces of chloride of sodium	3-90 ¹

This analysis presents several points worthy of consideration. The urea is much below the normal average, amounting to only 27% instead of 39% of the solid residue. The uric acid is much increased, for it amounts to 6-3%, whereas the normal average is only 1-5%; it must, however, be remembered that the uric acid from a very considerable sediment of urate of ammonia has been included, and that a certain amount of bile-pigment was associated with it. The fixed salts are below the normal average, amounting to only 19%, the earthy phosphates on the other hand amounted to 4-9%.

An analysis of the blood of this person has been given in page 269.

In common or chronic icterus, where, instead of there being febrile symptoms, the pulse becomes slower as the disease advances, the urine is at first of a dark red colour, after a time it becomes of a dark brown, and often, according to Schönlein, of an inky tint: towards convalescence it clears up, and gradually returns to the normal state.

¹ The biliary resin and biliverdin were taken up by anhydrous alcohol with the urea and alcohol-extract. On evaporating the alcohol and adding water, the biliary resin and biliverdin were precipitated; this latter was separated from the resin by digestion in a weak solution of ammonia, which on evaporation left the green colouring matter.

I made an analysis of the urine of a man suffering from icterus, anaæræca, and haemoptysis, who was being treated in our hospital.

This analysis corresponded closely in its results with the preceding one.

The urine was of a brownish red colour, very turbid, had an acid reaction, and deposited two layers of sediment, the under one of a lateritious appearance, and the upper of a brown colour; both consisted of urate of ammonia coloured partly with uroerythrin and partly with biliphæin. The urine became perfectly clear on being heated, and at the boiling point gave no indications of albumen. Nitric acid caused no precipitate, but produced the well-known shades of colour dependent on the presence of bile-pigment. The specific gravity was 1014.

The urine contained:

	Analysis 148.
Water	962.80
Solid constituents	37.20
Urea	10.90
Uric acid	1.01
Urate of ammonia	3.51
Fixed salts	6.70
Earthy phosphates	0.74

The urea in this case amounts to only 29% of the solid residue, and the uric acid independently of the urate of ammonia to 2.7%, the latter alone amounting to 9%: the salts are diminished, with the exception of the earthy phosphates, which are increased, and amount to 2%.

[Scherer¹ mentions a case of long-standing icterus, dependent apparently on chronic inflammation of the parenchyma of the liver, in which the urine, on emission was clear, yellow, and perfectly neutral, but after standing three or four hours became acid and deposited uric acid combined with a large amount of bile-pigment as an amorphous, yellowish-brown, flocculent mass. The development of the acid (lactic, according to Scherer) proceeded rapidly, and in the course of twenty-four hours the yellow colour of the urine became converted into a blackish green. The deposition of the sediment and the change of colour could be more speedily induced by the addition of a few drops of acetic or hydrochloric acid to the fresh urine. The specific gravity was 1018, and in 1000 parts there were 42.5 of solid residue, including only 4.3 parts of urea, while there were no less than 1.8 of uric acid. In the course of ten weeks he had much improved, and was able to take exercise in the open air. The solid constituents were then reduced to 35.6, and the uric acid to 0.6, while the urea rose to 12.4. The urine of this patient contained a large quantity of silica.]

¹ Untersuchungen, &c. p. 59.

Hysteria.

In attacks of hysteria the urine is often, but not invariably, remarkable for its clear limpid appearance, and for the extremely small quantity of solid constituents which it contains: in fact, it is sometimes very like common water.

Becquerel observes that, in nervous attacks, the urine is not always spastic and secreted in large quantity, but that it sometimes resembles the normal secretion, and in certain cases he even found it deeply coloured, of high specific gravity, loaded with uric acid, and occasionally depositing a sediment.

He observed similar variations in the urine at the commencement of an attack of hemicrania.

Nysten mentions an analysis of nervous urine, which was perfectly limpid, had an acid reaction, contained more urea than the urina potūs, but, on the other hand, less uric acid and salts. According to Rollo, urea and the organic constituents are wanting in spasmodic urine, and it contains only the ordinary salts.

In cramp of the stomach, Gmelin found the urine darker than usual; it contained bile-pigment, which was, however, somewhat modified, since on being precipitated with hydrochloric acid, and being again dissolved in potash, it gave a beautiful red with nitric acid, without previously going through the green and blue tints.

Marasmus senilis.

[Scherer¹ has published an analysis of the urine in a case of marasmus senilis accompanied with gangrene.

It contained in 1000 parts:

Water	-	-	-	-	-	927.45
Solid constituents	-	-	-	-	-	72.55
Urea	-	-	-	-	-	17.52
Uric acid	-	-	-	-	-	1.70
Alcohol-extract	-	-	-	-	-	13.23
Water-extract	-	-	-	-	-	15.00
Soluble salts	-	-	-	-	-	20.00
Earthy phosphates	-	-	-	-	-	4.67

The amount of soluble salts and earthy phosphates is remarkably large.

A man aged 29 years, labouring under marasmus from sexual abuses, was observed by Dr. Golding Bird to pass daily thirty-six ounces of urine of specific gravity 1024.

The water amounted to	-	-	-	-	-	15227 grains.
The solids	-	-	-	-	-	901
Urea	-	-	-	-	-	369.6
Uric acid	-	-	-	-	-	36.0]

Carcinoma.

The urine in scirrhous ventriculi is, as Berzelius has remarked, sometimes turbid, has a milky look when it is discharged, and

¹ Untersuchungen, &c. p. 75.

deposits a white sediment of mucus and phosphate of lime; Fromherz and Gugert also found mucus and earthy phosphates in the urine of a person who was liable to frequent vomiting in consequence of scirrhous of the pylorus; the urine was alkaline from the presence of carbonates of soda and ammonia, and contained no uric acid, but much urea.

In opposition to these statements I found the urine secreted in small quantity, deeply coloured, without a sediment, and with a very acid reaction, in an advanced case of scirrhous ventriculi, occurring in a man in Schölein's clinical ward, who vomited matter like coffee grounds.

Four days afterwards, when the vomiting was partially checked by the use of morphia, the urine was turbid and jumentous: it continued acid, and subsequently formed a copious sediment of urate of ammonia, while the clear urine above the precipitate was so dark that bile-pigment was suspected to be present, which, however, was not the case. The urine continued to throw down sediments till the death of the patient, which occurred not long afterwards; it became, however, of a brighter colour.

Becquerel observes that in cancer of the stomach he has found the urine normal, when there has been but little functional disturbance: dark, sedimentary and very acid, when there has been severe pain and frequent vomiting: and, finally, he has found it anaemic in cases in which the physical powers have been reduced to the lowest ebb by the disease.

In cancer of the liver, Becquerel found the urine undergo the same modifications that I have described as occurring in cancer of the stomach. It was very dark, very acid, of high specific gravity (1023—1026,) and threw down a copious red sediment.

In cirrhosis of the liver, Becquerel found the urine much the same as in cancer, except that when the cirrhosis was accompanied by icterus, bile-pigment found its way into the urine.

[I am indebted to Dr. Percy for the following analysis of the urine of a man labouring under deep and permanent jaundice consequent on true carcinoma of the liver, of which he died.

The urine contained in 1000 parts:

Water	-	-	-	-	-	979-00
Solid residue	-	-	-	-	-	21-00
Urea	-	-	-	-	-	3-76
Indeterminate organic matter	-	-	-	-	-	8-78
Salts soluble in water	-	-	-	-	-	8-18
Salts insoluble in water	-	-	-	-	-	0-28

It was deeply tinged with bile-pigment, but deposited no sediment.

The small amount of urea may be accounted for by the fact of great emaciation consequent on long previous mal-assimilation, and the small amount of metamorphosis of tissue occurring in the patient.]

Syphilis.

[Heller examined the urine of a man aged 38 years, who was taking iodide of potassium for a syphilitic eruption accompanied with pains in the bones. When the urine was first examined he was taking two scruples daily in three ounces of distilled water; on the second occasion (four days afterwards) he was taking additionally half a grain of iodine.

		1.	2.
Specific gravity	-	1015	1021
Water	-	974.800	954.40
Solid constituents	-	25.200	45.60
Urea	-	7.736	13.82
Uric acid	-	0.310	0.51
Extractive matters and hydrochlorate of ammonia	}	6.433	12.15
Fixed salts, including iodide of potas- sium	}	10.520	19.32

The urine on the first occasion was excreted in about the normal quantity, was of a dark-yellow colour, and had an acid reaction: on the second occasion it was of an intensely dark-yellow colour, and its reaction was faintly alkaline; its amount was also diminished. No albumen or biliphaein was present in either case.

After the continuance of the second prescription for eight days, the urine of twenty-four hours was collected with the view of ascertaining the amount of iodine removed by the kidneys. The whole daily urine amounted to 850 grammes or 24.5 ounces.

In order to estimate the amount of iodine, 200 grammes of urine were evaporated, the residue dissolved in water, and ammonia added to the filtered solution till it exhibited a strongly alkaline reaction. On the addition of nitrate of silver a precipitate was thrown down which was washed with a weak solution of ammonia, dried, and weighed.

From the 200 grammes of urine 0.94 of iodide of silver were obtained, containing 0.507 of iodine; hence 1000 parts of urine contained 2.535 of iodine, corresponding to 3.322 of iodide of potassium. Consequently, in the whole daily amount of urine there were contained 2.824 grammes or 38.689 grains of the iodide. Now the 40 grains of iodide of potassium and half grain of iodine may be regarded as equivalent to 40.626 grains of the iodide alone (for iodine is always in a state of combination when it occurs in the secretions,) and consequently the whole of the iodide was removed by the kidneys, with the exception of nearly two grains which were distributed partly to the saliva, sweat, nasal mucus, &c., and partly remained in the blood.]

Skin-diseases.

[The urine in a case of urticaria tuberculosa has been analyzed by Scherer. The patient was a young man who likewise suffered from rheumatism. The urine was discharged in very small quantity, often not more than five or six ounces in forty-eight hours. It was

clear, of a brownish-red colour, very acid, and its specific gravity was 1028.

It contained in 1000 parts:

Water	-	-	-	-	-	931-58
Solid residue	-	-	-	-	-	68-42
Urea	-	-	-	-	-	30-46
Uric acid	-	-	-	-	-	0-74
Alcohol-extract with much lactic acid	-	-	-	-	-	21-24
Water-extract	-	-	-	-	-	4-92
Alkaline salts	-	-	-	-	-	8-03
Earthy phosphates	-	-	-	-	-	2-03

The most remarkable points in the constitution of the urine are the large amount of earthy phosphates, and the excess of free acid.

Heller¹ has published three analyses of the urine in cases of herpes zoster.

1. A boy aged 8 years; eruption on the right side, no fever, urinary secretion abundant. The urine was of a pale yellow colour, rather turbid, rapidly became putrid, and deposited a sediment of beautifully-formed crystals of ammoniaco-magnesian phosphate.

The urine was faintly alkaline on emission, and its specific gravity varied from 1014 to 1015.

It contained in 1000 parts:

Water	-	-	-	-	-	970-00
Solid constituents	-	-	-	-	-	30-00
Urea	-	-	-	-	-	8-94
Uric acid	-	-	-	-	-	traces
Fat	-	-	-	-	-	0-14
A little extractive matter with a large amount } of hydrochlorate and carbonate of ammonia }	-	-	-	-	-	9-32
Fixed salts	-	-	-	-	-	11-60
consisting of,						
Earthy phosphates	-	-	-	-	-	2-00
Chloride of sodium	-	-	-	-	-	4-154
Sulphate of potash	-	-	-	-	-	0-164
Phosphate and carbonate of soda, &c.	-	-	-	-	-	5-283

No trace of hippuric acid could be discovered.

2. A man aged 31 years; eruption on right side, slight fever. Urinary secretion considerably suppressed, the urine analyzed being the first that had been passed for twenty-four hours. In a few hours it formed a sediment of ammoniaco-magnesian phosphate and urate of ammonia.

It was strongly alkaline, and its specific gravity was 1028.

It contained in 1000 parts:

Water	-	-	-	-	-	944-40
Solid constituents	-	-	-	-	-	55-60
Urea	-	-	-	-	-	15-79
Uric acid with a little urate of ammonia	-	-	-	-	-	1-80
Fat	-	-	-	-	-	0-34
Extractive matters with much hydrochlorate } and carbonate of ammonia }	-	-	-	-	-	21-35
Fixed salts in the sediment	-	-	-	-	-	0-43
Fixed salts in the urine	-	-	-	-	-	16-32 } 16-75

¹ Archiv, vol. 1, pp. 39-43.

consisting of,					
Earthy phosphates	-	-	-	-	2.85
Chloride of sodium	-	-	-	-	5.10
Sulphate of potash	-	-	-	-	0.15
Phosphate of soda, &c.	-	-	-	-	8.24

3. A young man aged 19 years; eruption chiefly on left side, no fever. The urine was very clear. In the course of twelve hours it became turbid and deposited beautiful crystals of ammoniac-magnesian phosphate. Specific gravity 1018.

The urine contained in 1000 parts:

Water	-	-	-	-	958.90
Solid constituents	-	-	-	-	41.10
Urea	-	-	-	-	14.20
Uric acid	-	-	-	-	0.90
Fat	-	-	-	-	0.12
Extractive matters, much hydrochlorate of ammonia, &c.	-	-	-	-	12.14
Fixed salts	-	-	-	-	14.44
consisting of,					
Earthy phosphates	-	-	-	-	2.60
Chloride of sodium	-	-	-	-	5.40
Sulphate of potash	-	-	-	-	0.08
Phosphate and carbonate of soda, &c.	-	-	-	-	6.36

From these analyses we may conclude that in herpes zoster the chief peculiarities of the urine are:

1. A marked increase of the chlorides and phosphates, and a corresponding diminution of the sulphates.
2. An excess of hydrochlorate of ammonia.
3. A large amount of fat.
4. A diminution in the amount of uric acid. An increase only occurs when the disease is accompanied with fever.

The presence of oxalate of lime may always be suspected in these cases.

The urine in a case of pompholix has also been analyzed by Heller. The patient was a woman aged 40 years; the attack was very severe and proved fatal. The urine deposited a light cloudy sediment consisting principally of mucus, but also containing fat-globules, urate of ammonia, and a few epithelium-scales. It was acid, and its specific gravity was 1017.5.

It contained in 1000 parts:

Water	-	-	-	-	-	955.80
Solid constituents	-	-	-	-	-	44.20
Urea	-	-	-	-	-	24.63
Uric acid	-	-	-	-	-	0.58
Extractive matters	-	-	-	-	-	11.79
Fixed salts	-	-	-	-	-	7.20

Of the fixed salts the earthy phosphates were normal, the sulphates much increased, and the chloride of sodium proportionally diminished. The urea is considerably above the normal average.]

**ON SOME OTHER MODIFICATIONS OF THE URINE INDUCED BY
DISEASE.**

Fat in urine.

There are certain morbid conditions in which fat is excreted in a free state with the urine, which, at the same time, is neither chylous nor milky, nor contains any large amount of albumen or casein. Urine of this sort most commonly occurs in those diseases in which there is a very rapid loss of substance and force. I have on several occasions detected fat in the urine of phthisical persons, and on two occasions I have found it during tabes. I have already (see page 437) explained in what manner the presence of fat may be detected with certainty; I would here add a word of caution, that the presence of fat from extraneous sources, as improperly cleaned glasses, &c. must be carefully guarded against.

Such cases as that which is related by Bachetoni,¹ in which a noble young lady is reported to have discharged two ounces of olive oil with the urine on different occasions, must at least be regarded as mysterious; Elliottson² also witnessed the daily discharge of about one third of an ounce of oil with the urine of a woman suffering from biliary calculi.

[A case of fatty urine has been recently described by Dr. Golding Bird (*Urinary Deposits*, page 263.) An analysis of this form of urine has likewise been given in page 469 of this volume.]

Milk in urine.

In speaking of diabetes I adverted to chylous urine, and said a few words regarding milky urine. It appears from an essay of Rayer, in which he enters fully into the subject, that this form of morbid urine is extremely rare; but that the term 'milky urine' has frequently been applied incorrectly to the fluid simply from its having a turbid or emulsive appearance, while there has been no trace of casein, but the fat has been suspended by means of albumen.

The only recorded cases of actual milky urine containing casein and fat, are one by Canubio, of a woman who was suckling; one by Alibert, of a healthy young widow; and, lastly, a case by Graves.

Excess of hippuric acid in urine.

[There are certain conditions of the system in which an excess of hippuric acid occurs in the urine, independently of those cases in which benzoic or cinnamic acid is taken either in the food or as medicine.

¹Comment. Bonon. Pars I, ad ann. 1787.

²On the discharge of fatty matters from the alimentary and urinary passages. (*Medico-Chirurg. Transactions*, vol. 18, p. 80.)

The following case is recorded by Bouchardat.¹

A lady aged 53 years, suffering from lassitude, dry skin and tongue, occasional pain in the region of the liver, loss of appetite, and great thirst, passed a large quantity of limpid urine possessing an odour of whey. Its specific gravity varied from 1006 to 1008; it slightly reddened litmus paper, and contained in 1000 parts:

Water	-	-	-	-	986-00
Solid constituents	-	-	-	-	14-00
Urea	-	-	-	-	1-56
Hippuric acid	-	-	-	-	2-23
Lactate of soda	-	-	-	-	2-96
Albumen	-	-	-	-	1-47
Mucus	-	-	-	-	0-20
Chloride of sodium	-	-	-	-	2-75
Phosphate of soda	-	-	-	-	0-97
Alkaline sulphates	-	-	-	-	1-44
Earthy phosphates	-	-	-	-	0-42

Dr. Garrod² has narrated the case of a man suffering from pain in the loins and symptoms of atonic dyspepsia, with flabby, white furred tongue, who excreted a considerable amount of hippuric acid.

When examining the urine for the purpose of ascertaining the proportion of uric acid by the addition of a small quantity of hydrochloric acid, he found the tube filled with crystals of hippuric acid, and on these large crystals smaller ones of uric acid were deposited. For several days he found as much as half a drachm in six ounces of urine, or about 10 of hippuric acid in 1000 parts. It afterwards gradually diminished, requiring considerable evaporation before crystals were deposited, and ultimately disappeared. The patient had previously suffered from voiding an excess of urea, and his urine had contained a deposit of ammoniaco-magnesian phosphate.

Dr. Pettinkoffer³ has also published an analysis of urine containing an excess of hippuric acid. The patient was a girl aged 13 years, suffering from chorea. The urine was limpid and acid on emission, but soon became alkaline and deposited crystals of ammoniaco-magnesian phosphate. After pouring nitric acid on the evaporated alcoholic extract with a view of determining the amount of urea, Dr. Pettinkoffer was surprised to find that instead of the usual crystalline plates of nitrate of urea, brownish yellow needles made their appearance. Under the microscope the needles were found to be six-sided prisms, in some places intermingled with plates of nitrate of urea. The urine evidently contained a large amount of hippuric acid in combination with potash or soda, from which the nitric acid separated it. When the alcoholic extract of the urine was evaporated, mixed with hydrochloric acid, and allowed to stand, four-sided prismatic crystals of hippuric acid were deposited.

1000 parts of urine contained 40-668 of solid residue, of which 31-251 were soluble in spirit, and consisted of hippurates, urea, extractive matters, and chlorides; while the remaining 9-417 were com-

¹ Annuaire de Thérapeutique, 1842, p. 285.

³ Liebig's und Wöhler's Annalen, vol. 50, No. 1.

² Lancet, Nov. 16, 1844.

posed of urates, phosphates, and sulphates, together with mucus and water-extract.

The solid residue yielded, on incineration, 10.599 of fixed salts.

On the following day, 1000 parts of urine yielded 49.825 of solid residue and 12.985 of ash, consisting of:

Carbonates of lime and magnesia	-	-	1.153	} 1.866 insoluble in water
Earthy phosphates	-	-	0.713	
Carbonate of soda	-	-	3.996	
Chlorides of sodium and potassium	-	-	6.181	
Phosphate of soda	-	-	0.128	
Sulphate of lime	-	-	0.614	

If we consider that the alkaline carbonate in the ash corresponds with the hippurate in the urine, then 1000 parts of urine must have contained 12.886 of anhydrous hippuric acid, and 100 parts of solid residue 25.8 of the same constituent. During this period the only food taken by the girl was bread, apples, and water; she, however, gradually resumed her ordinary diet, and the excess of hippuric simultaneously disappeared.]

Urostealith in urine.

[Heller¹ has recently announced the discovery of a new constituent of urinary calculi, to which he has given the name *urostealith*. It is soluble in carbonate of soda; and when that remedy is administered, urostealith in a state of solution is found in the urine.

The patient was a man of tolerably good constitution, aged 24 years; he complained of pain in the region of the right kidney, and difficulty in micturition, occasionally passing small elastic soft concretions. These were examined by Heller, and found to be perfectly soluble in alkalies, with which they formed a soap.

Analysis of the urine before the administration of carbonate of soda.—25th Feb. The urine had a light yellow, whey-like appearance, no odour, and deposited a sediment of ammoniaco-magnesian phosphate. Fat-globules were detected under the microscope. The reaction was neutral; the specific gravity 1017.5. It contained in 1000 parts:

Water	-	-	-	-	-	965.900
Solid constituents	-	-	-	-	-	34.200
Urea	-	-	-	-	-	12.631
Fat	-	-	-	-	-	0.390
Extractive matters with much hydrochlorate of ammonia	-	-	-	-	-	8.669
Fixed salts	-	-	-	-	-	12.680
consisting of,						
Earthy phosphates	-	-	-	-	-	2.040
Chloride of sodium	-	-	-	-	-	0.163
Sulphate of potash	-	-	-	-	-	2.296
Basic phosphate of soda and peroxide of iron	-	-	-	-	-	8.181
						12.680

Moreover, every 1000 parts of urine threw down 0.62 of pure ammoniaco-magnesian phosphate. Not a trace of uric acid could be detected.

¹ Archiv für phys. und patholog. Chemie, vol. 2, p. 1.

28th Feb. The day after the carbonate of soda had been given the urine was neutral, of a pale yellow colour, and had a specific gravity of 1006. Fragments of urostealth were detected in the sediment, mixed with ammoniaco-magnesian phosphate. No uric acid was present.

By the 2d of March the calculus of urostealth was almost entirely dissolved. The reaction of the urine was neutral; the addition of ammonia produced a reddish brown tint; (this is regarded by Heller as a test for urostealth;) uric acid was still absent. The specific gravity was 1020. The urine contained in 1000 parts:

Water	959-90
Solid constituents	40-10
Urea	11-20
Fat and urostealth	3-40
Extractive matters and hydrochlorate of ammonia	8-29
Fixed salts	17-21

No sediment was deposited. In order to obtain the urostealth, a large quantity of urine was evaporated, and sulphuric acid added in order to decompose the soap. The urostealth was taken up by boiling ether, which, on evaporation, yielded a violet tint. For further information on the chemical characters of this substance I must refer to Chapter XII.]

Semen in urine.

It may sometimes be of importance to ascertain whether the urine contains any seminal fluid. This point can be best settled by the microscope. We find mucous floccules in the urine; and if semen is present, the spermatozoa will be detected amongst them. They are represented in fig. 33.

Urine of peculiar colours.

Some cases have been recorded in which the colour of the urine has deviated extremely from the normal type. A case is related by Janus Plaucus, in which a dark blue sediment was precipitated from the urine of a man 60 years of age, a short time before his death. He had formerly suffered from dysuria and vesical calculus, and subsequently from typhus fever.

Marcet, Prout, Braconnot, Babington, Garnier, Spangeberg, and others, have observed blue and black urine. I have related a case in which the urine deposited a blue sediment, in page 502.

I have made an examination of the urine passed by a man at Gräfenberg, who had spent many years in the East Indies, and returned to Europe for the benefit of his health. It had a strong ammoniacal odour, was of a clear blue colour, and deposited a somewhat copious dark-blue sediment, which appeared, from a microscopic examination, to consist of very fine amorphous matter (on which the blue colour was dependent) and a few crystals of ammoniaco-magnesian phosphate. On treating a portion of the washed and dried

sediment with caustic potash, the colour did not disappear; hence it was not dependent on the presence of iodide of starch or Prussian blue. Dilute organic acids and hydrochloric acid neither dissolved it nor destroyed its colour; but on digesting it in nitric acid, the tint changed from blue to yellow. Digested in concentrated sulphuric acid, it dissolved, forming a solution of an indigo colour. On warming a portion of the sediment on platinum foil, it first evolved a urinous odour, and subsequently volatilized, going off in deep violet-coloured vapour. The most convincing proof that the blue tint was due to indigo, was that on warming a portion of the sediment with dilute alcohol to which grape sugar and potash had been added, the fluid lost its blue tint, and assumed a yellowish-red colour, which, on shaking, was converted into an intense blood-red, and then rapidly into a green. On allowing it to rest the green tint disappeared, and the fluid assumed a yellowish-red colour. All these phenomena led to the conclusion that the colouring matter was indigo. I have since heard that specimens of the same urine were sent to Bouchardat, Liebig, and Prout, who coincide in the opinion that the pigment was not indigo, but a distinct organic compound. No indigo, or indeed medicine of any sort had been recently taken by the patient.

Dulk¹ has observed and analyzed black urine passed by a person suffering from derangement of the liver and portal system.

[Dr. v. Velsen² has published the case of a man aged 84 years, with chronic cystitis, who passed very fetid urine of a deep violet colour, after the use of lime-water mixed with warm milk. After the omission of the draught for a few days, the peculiar colour disappeared.]

Urine during pregnancy, at the period of delivery, and after delivery.

Since Nauche's announcement (a few years ago) of the discovery of a peculiar substance to which he gave the name of *kystein*, in the urine of pregnant women, the renal secretion during this state has been carefully examined by numerous chemists.

Nauche describes kystein as a white mass that, after the urine has stood for some time, separates, partly rising to the surface, where it forms a somewhat tough pilous membrane interspersed with glistening crystals, and partly sinks to the bottom, forming a creamy precipitate. Nauche regards kystein as an indubitable sign of pregnancy. It is also considered a certain test by Eguiser; he states that it appears after the urine has stood two to six days, depositing itself as a white opaque body, and then rising to the surface and producing a film like the solid fat that settles on cold broth. From an extensive series of observations, Dr. Kane concludes that kystein does not appear sooner than thirty hours, or later than eight days; that on its first appearance it forms a scarcely perceptible membrane, which gradually becomes firmer and thicker, and after a time, breaks up,

¹ Archiv der Pharmacie, vol. 18, p. 159.

² Casper's Wochenschrift, 1844, No. 18.

the fragments sinking to the bottom; that a kystein-like membrane may also appear in the urine of persons with phthisis, arthritis, metastatic abscesses, vesical catarrh, &c., but that it differs from true kystein, both in the manner of its formation and of its destruction; it appears later than the true kystein, but, having once appeared, develops itself more rapidly and possesses less tenacity. The urine is neutral or ammoniacal on the appearance of the kystein, which, under the microscope, appears as an amorphous matter consisting of minute opaque corpuscles, intermingled with crystals of ammoniacomagnesian phosphate. Dr. Kane convinced himself that the occurrence of kystein was independent of the presence of albumen; he likewise ascertained that it occurs not only during pregnancy but also during the period of lactation, especially when the secretion of milk is at all checked. He concludes with the observation that "when pregnancy is possible, the exhibition of a clearly-defined kystein-pellicle is one of the least equivocal proofs of that condition, and that when, in a case of suspected pregnancy, this pellicle is not found, if the female be healthy, the probabilities are as twenty to one that the prognosis is incorrect."¹ It appears from a review of Kane's cases, that the kystein most commonly appears on the third day; in one case, however, it could not be observed till the eighth day after the urine had been passed; and in some cases it appeared during the first twenty-four hours.

During the first weeks of pregnancy, Kane only rarely observed it; it was most commonly noticed during the seventh, eighth, and ninth months, and up to the period of delivery. In eighty-five cases of pregnancy it was absent eleven times, and was present in thirty-two out of ninety-four cases examined during lactation.

I have examined the urine during the second, third, fourth, fifth, and sixth months of pregnancy, but have not invariably detected kystein. In the cases in which it was formed, as in the second, fifth, and sixth months of pregnancy, the urine on emission was clear, yellow, faintly acid, and not affected either by nitric or acetic acid, or by heat. Usually, in about twenty-four hours, the whole urine became slightly turbid, the acid reaction disappeared, a white viscous sediment was deposited, and soon afterwards the surface of the fluid became covered with a pellicle at first extremely delicate, but after from twelve to twenty-four hours becoming tough, thick, opaque, and with a glistening appearance in consequence of the light reflected from numerous minute crystals of ammoniacomagnesian phosphate with which it was studded. On examining this pellicle in its early state under the microscope, it appeared (when magnified 300 times) to consist of an amorphous matter composed of minute, opaque points, such as are presented by sediments of phosphate of lime or urate of ammonia, except that in the latter the individual particles are usually darker, more clearly defined, and larger than in kystein. The whole field of vision was likewise bestrewed with numerous vibriones in

¹ American Journal of Med. Science, July, 1842.

active motion, and crystals of ammoniaco-magnesian phosphate. When the pellicle became thicker, precisely similar phenomena were observed, but the vibrios were supplanted by a considerable number of monads; on the addition of acetic acid the crystals disappeared, while the amorphous matter remained unaffected. On digesting the pellicle in acetic acid, and adding ferrocyanide of potassium to the filtered solution, a comparatively slight turbidity ensued, but on macerating the pellicle in a dilute solution of potash, acidulating the filtered solution with acetic acid, heating, and adding ferrocyanide of potassium after a second filtration, a more decided turbidity was observed. From these experiments I concluded that a protein-compound was present. The white sediment, that occurred after the urine had stood for some days, possessed a disagreeable, pungent, caseous odour: under the microscope it presented the same appearance as the pellicle. After repeatedly washing a portion of the sediment with water, and then heating it with alcohol and a little sulphuric acid, it developed a disagreeable fruit-like odour, reminding me of butyric ether. [We shall presently show that the accuracy of this observation has been thoroughly established by Lehmann.] It results from the above observations, that kystein is not a new and distinct substance, but a protein-compound, whose formation is undoubtedly and closely connected with the lacteal secretion. From the observations of Kane and myself, it seems to follow that pregnancy may exist without the occurrence of kystein in the urine; if, however, there is a probability or possibility of pregnancy, and kystein is found in the urine, then the probability is reduced almost to a certainty. We are unable to draw any positive inferences respecting the stage of pregnancy from the appearance of the kystein.

A deposit of caseous matter and earthy phosphates was frequently observed by Golding Bird in the advanced stages of pregnancy. The sediment is probably similar to Nauche's kystein.

Every urine left to itself forms a pellicle, more or less resembling that of kystein. If formed soon after the urine is discharged, it consists of earthy phosphates, which, from the urine being alkaline, are, for the most part precipitated, but likewise form a delicate film on the surface. When this is the case, the pellicle is very thin and readily sinks to the bottom. Under the microscope crystals of ammoniaco-magnesian phosphate, and an amorphous matter very similar to kystein, but consisting of phosphate of lime, are observed: this likewise differs from kystein in being soluble in free acids. A pellicle of fat on the surface of urine may sometimes be mistaken for kystein: films of this nature are very thin and usually iridescent, and the microscope reveals the presence of numerous fat-globules.

The membrane formed on the surface of urine six or eight days after emission, usually consists of a species of mould; under the microscope there may be seen innumerable filaments matted together, and interspersed with sporules.

I once observed a pellicle on the surface of a man's urine three

days after emission, which both in chemical and microscopical characters presented the closest analogy to kystein.¹

[Lehmann² frequently examined the urine of a pregnant woman from the second to the seventh month. It was of a dirty yellow colour, and more inclined to froth than usual; it generally became turbid in from two to six hours; but the morning urine, after standing for thirty-six or forty-eight hours, was always covered with a grayish-white film, which often, in two or three days, sank and mixed with the sediment that formed when the turbidity appeared, but sometimes was a longer period before it broke up. By means of ether he could always remove from this film a considerable quantity of viscid fat, which formed a soap with potash, and then, on the addition of sulphuric acid, developed a well-marked odour of butyric acid. On treating a large quantity of this urine with sulphuric acid, and distilling, he obtained, after treating the distillate with baryta water, brilliant crystals of butyrate of baryta. The substance taken up by ether, when gently evaporated with nitric acid and exposed to the vapour of ammonia, was not in the least reddened; with concentrated hydrochloric acid, on the other hand, it assumed a blue tint; dissolved in potash, boiled, and treated with hydrochloric acid, it developed sulphuretted hydrogen; it dissolved tolerably freely in acetic acid, from which it was precipitated by ferrocyanide of potassium. These reactions left no doubt of its being a protein-compound. The portion of the film insoluble in potash consisted chiefly of phosphate of magnesia, [ammoniaco-magnesian phosphate?] with a little phosphate of lime. Hence Lehmann concludes that the kystein of Nauche is not a new and distinct substance, but a mixture of butyaceous fat, phosphate of magnesia, and a protein-compound very similar to casein. He likewise mentions that, in examining the urine of a woman who was not suckling, and was kept on very low and sparing diet, on the third, fourth, sixth, and ninth days after delivery, he found a large quantity of butyric acid taken up by ether from the solid residue; and on dissolving the ethereal extract in water, adding sulphuric acid, and distilling, he obtained a further quantity. The urine in this case was always rather turbid, of a dirty yellow colour, very acid, and contained a very small amount of uric acid.

Möller³ relates two cases in which the urine of women who were not pregnant was covered with a film exactly resembling kystein; in one case there was considerable hypertrophy of the uterus; in the other no affection of the generative organs could be detected. The film of kystein consists, according to his observations, of fat, earthy phosphates, and a caseous matter, which differs, however, from the casein of milk in being held in solution by a free acid. When the

¹ [A similar appearance has been observed by Prout in the urine of a delicate child, fed chiefly on milk. (On Stomach and Renal Diseases, 4th edit. p. 555, note.)]

² Lehrbuch der physiologischen Chemie, vol. 1, p. 232.

³ Casper's Wochenschr. Jan. 11-18, 1845.

urine becomes neutral or alkaline, the caseous matter ceases to be held in solution, and separates as kystein. Every thing checking the decomposition of the urine hinders the formation of the pellicle, and if the recent secretion is treated with a free acid (mineral or organic;) no separation of kystein takes place even if ammonia be added to saturation, or decomposition allowed to proceed to any extent.

In a case of decided pregnancy, no kystein was formed during the period of a severe cold, attended with a copious deposition of urates; but when the urine became natural, the kystein reappeared. He twice detected cholesterol in kystein.

Kleybolte¹ has examined the urine in ten cases of pregnancy, and invariably found kystein on the fifth day. The morning secretion was used, and, after being slightly covered to protect it from dust, was allowed to stand, at an ordinary temperature, for ten days. The following appearances were observed in the tenth week of pregnancy: urine peculiarly yellow, with a greenish tint. 2d day, mucous sediment; 3d day, no change; 4th day, turbidity ascending from the bottom; 5th day, white points and leaflets on the surface, turbidity ascending from all parts of the bottom, and the sediment almost gone; 6th day, kystein distinctly observed on the surface, like lumps of fat on the surface of cold broth; 7th day, no change. From the 8th to the 10th day, the kystein disappears, the turbidity again descends, and the sediment noticed on the 2d day is reproduced. The nine remaining cases are in most respects similar to the above.

A few observations on kystein have been recently published by Audouard,² but contain nothing of importance, except that in six specimens of urine passed by young women suffering from amenorrhœa, he found kystein in five.³]

I shall now give a short abstract of Becquerel's researches. During pregnancy, the general state of the system is liable to great variations, and the urine presents differences of corresponding importance. If good health is enjoyed during pregnancy, the urine remains normal; if, however, any thing should happen to excite the vascular system, it readily changes, becoming dark-coloured, acid, sedimentary, and diminished in quantity. During the latter stages of pregnancy the urine often assumes the anaemic type, that is to say, it becomes pale, contains only a small amount of solid residue, and the specific gravity does not exceed 1011. The observations which were communicated by Donné in a letter addressed to the Academy of Sciences, dated May 24, 1841, in reference to the urine in pregnancy containing less free acid, and less of the phosphate and sulphate of lime than normal urine, were not confirmed by Becquerel. Neither could Becquerel observe kystein.

After delivery, mucus tinged with blood, is mixed with the urine; this is succeeded by the discharge which is known as the lochia.

¹ Casper's Wochenschrift, April 26, 1845.

² Journal de Chemie Méd. May, 1845.

³ Many other communications have recently been published on this subject, which I do not deem necessary to notice, as they are, for the most part, simply confirmatory of the above observations.

During the period that intervenes between delivery and the commencement of the milk-fever, the urine either assumes the inflammatory type, and is scanty, high-coloured, acid, and dense, as, for instance, in those cases in which the labour has been very difficult and painful, and the vascular system is much excited; or it takes on the anaemic form, as in those cases in which the labour is followed by great debility and prostration.

Becquerel gives two analyses: one was made with the urine of a woman aged 33 years, who, the previous evening, had been delivered of a dead child; pulse 96, strong; urine of a deep red colour, acid, and sedimentary; the sediment was mixed with sanguineous mucus, and there was a little albumen in the urine.

The second analysis was made with the urine of a woman aged 22 years, who had been delivered forty-eight hours previously of a seven months dead child. Pulse 92, rather weak; urine was very red, and held in suspension a cloud of sanguineous mucus and a considerable quantity of albumen.

	1.	2.
Quantity of urine in 24 hours in ounces	30	26·5
Specific gravity	1012·6	1018·0
1000 parts contained:		
Water	979·5	970·2
Solid constituents	20·5	29·8
Urea	6·5	7·8
Uric acid	0·5	0·5
Fixed salts	4·6	7·4
Extractive matters	9·5	10·6
Albumen	—	3·3

We see from the ratio of the urea and also of the uric acid to the solid residue, that the urine in neither of these cases can be regarded as inflammatory, but that it rather approximates to the anaemic type. In the first analysis the urea amounts to only 31% and the uric acid to 2·4% of the solid residue; in the second analysis, the former amounts to 27% and the latter to 2%.

In most of the cases in which Becquerel examined the morning urine of women who had recently been delivered, he found it anaemic; the specific gravity varied from 1006 to 1014, the average being 1011.

As the milk-fever comes on, the chemical composition of the urine appears to undergo some modification, at least we are led to infer so from an analysis of Becquerel. It was secreted in diminished quantity, contained a larger proportion of urea and uric acid, was darker, and deposited a sediment.

He examined the urine of a woman aged 22 years, four days after delivery, while suffering from the milk-fever. It was of a saffron-yellow colour, deposited a sediment on the addition of nitric acid, and also spontaneously, after the lapse of some hours. In the course of twenty-four hours there were 15·5 ounces excreted. The specific gravity was 1031·5.

1000 parts contained:

Water	-	-	-	-	9482
Solid constituents	:	:	:	:	51·8
Urea	:	:	:	:	18·7
Uric acid	:	:	:	:	2·7
Fixed salts	:	:	:	:	11·3
Extractive matter	:	:	:	:	18·3
Albumen	:	:	:	:	0·7

Here the urea amounts to 36%, and the uric acid to no less than 5% of the solid residue.

On the passage of medicinal and other substances into the urine.

[All substances incapable of assimilation that enter the circulation are removed by the kidneys, either in the state in which they entered the organism, or in a modified condition.

Inorganic, non-metallic bodies. Iodine appears rapidly in the urine in combination with ammonium, (Lehmann,) sodium, and potassium. Bromine has been detected by Glover and Heller, and chlorine by Orfila.

Iodide of potassium, the alkaline borates, silicates, chlorates, and carbonates, as also chloride of barium, ferridcyanide of potassium, and sulphocyanide of potassium, were found by Wöhler¹ in the urine; the ferridcyanide was, however, converted into ferrocyanide in the system.

Sulphur has been found (after administration) in the urine by Wöhler and Orfila; and after the use of liver of sulphur, free sulphur, and an excess of sulphate of potash were found in the urine. In four experiments made by Laveran and Millon, sulphur neither appeared in the urine, nor was the quantity of sulphates increased.

Metallic substances. Arsenic and antimony may be readily detected in the urine, and have been observed by many chemists. The detection of mercury is by no means easy; it has been sought for in vain by Lehmann, L'Heretier, and Rees, but has been found by Buchner, Cantu, Jourda, Venables, Orfila, Cesterlen,² and Audouard.³ Iron is almost always present in the urine during its administration as a remedy. Nickel was found by Wöhler in the urine of a dog to whom he had given half a drachm of tartrate of nickel and potash. Gold, silver, tin, lead, and bismuth, were found in the urine of dogs to whom Orfila had given large doses of the soluble salts of those metals. Copper and manganese have been detected in the urine by Kramer.⁴

Inorganic acids. Orfila has detected nitric, hydrochloric, and sulphuric acids in the urine. As nitric acid is not a constituent of normal urine, there was no ambiguity in this experiment. In dogs poisoned with dilute hydrochloric or sulphuric acid, about six times as much chloride of silver and sulphate of baryta were obtained as are found in ordinary urine. In none of these cases was the urine

¹ Tiedemann's Zeitschr. für Physiol. vol. 1, p. 305.

² Journal de Chim. Méd. 9, p. 137.

³ L'Expérience, Aug. 1844.

⁴ Giornale dell' Instituto Lombardo.

more acid than usual, the acids having formed neutral salts by combining with the alkalies of the blood.

Organic acids and their salts. It appears from the investigations of Wöhler, that many of the organic acids, administered in a free state, enter the urine in a state of combination; as, for instance, oxalic, citric, malic, tartaric, succinic, and gallic acids.

To the above list Orfila has added acetic acid, and confirmed Wöhler's statement regarding oxalic acid.

According to Pereira¹ meconic acid may be occasionally detected in the urine of animals poisoned with opium.

One of the most important of Wöhler's discoveries is, that the neutral vegetable salts become modified in their passage through the system, and are found in the urine as carbonates. A few hours after the use of these salts, the urine becomes alkaline, is frequently turbid from the deposition of phosphates, and effervesces briskly on the addition of an acid.² If the dose is very large, oxalate of lime may frequently be detected. Similar results follow from the use of alkaline lactates; Lehmann found, that two hours after taking two drachms of lactate of soda, alkaline urine was excreted. That this change is effected after the salt has entered the blood, and not in the intestinal canal, is proved by an experiment performed by Mr. J. Goodsir, at my request. A drachm of acetate of potash was dissolved in an ounce and a half of water, and injected into the femoral vein of a dog, whose urine had been previously ascertained to be acid. The urine passed about an hour after the operation was alkaline. A similar experiment has been since made by Lehmann, who injected a drachm of lactate of potash into the jugular vein of a dog, and found the urine alkaline an hour afterwards. The process is one of simple combustion: each atom of acetic acid (of the acetate of soda) combines with eight of oxygen, and yields four atoms of carbonic acid and three of water, or $C_2H_3O_2 + 8O = 4CO_2 + 3HO$, and each atom of lactic acid combines with twelve of oxygen, forming six of carbonic acid and four of water, or $C_6H_5O_5 + 12O = 6CO_2 + 5HO$.

In a series of 268 experiments instituted by Millon and Laveran, with the tartrate of potash and soda, (Sodæ potassio-tartras. Ph. L.) they found the urine more or less alkaline in 175, acid in 87, and neutral in 6 cases. This apparent discrepancy was doubtless dependent on the degree of concentration of the saline solution. (See page 406.)

We have already mentioned that benzoic and cinnamic acids are converted in the organism into hippuric acid, and then excreted by the kidneys.

Vegetable bases. Quinine, when administered in large doses, has been noticed in the urine by Piorry, Landerer, and others. The best test for its presence is the iodated iodide of potassium, consisting

¹ Elements of Materia Medica, 1st ed. vol. 2, p. 1299.

² Some excellent observations on the physiological action of these salts will be found in Dr. Pereira's Treatise on Food and Diet, p. 29.

of four parts of iodide of potassium, one of iodine, and ten of water. The precipitate afforded by this reagent with disulphate of quinine is very insoluble in water, not affected by an excess of the test, and readily soluble in alcohol. It is of a yellowish-brown colour, and forms a turbidity or sediment, according to the amount of the alkaloid in the urine. When the quantity is very small there is merely an olive tint produced on the addition of the test. The disulphate of quinine may be reobtained from the sediment in a state of purity by a simple chemical process.¹

Morphia is stated to have been once detected by Barruel in the urine of a person under the influence of a poisonous dose of laudanum, and it was likewise discovered by Orfila, in the urine of dogs. None of the other alkaloids have yet been detected in the urine.

Indifferent organic substances. According to Wöhler, most colouring matters and many odorous principles passed unchanged or slightly modified into the urine. In the former class we may place indigo, gamboge, rhubarb, red beet-root, madder, logwood, mulberries, black cherries, &c.; in the latter, valerian, asafoetida, garlic, castoreum, saffron, turpentine, &c.

Alcohol is placed by Wöhler amongst the substances that do not enter the urine, and Liebig has recently affirmed that it has never been found in that secretion. It has, however, been detected by Percy in the urine of a dog, into whose stomach four ounces of spirit of '85 had been injected, and in the urine of a man in a state of intoxication who had taken about a bottle of whiskey. In both cases he obtained, by careful distillation, an inflammable fluid that dissolved camphor.²

In order to ascertain whether alcohol, taken in moderate quantity, would enter the urine, my friend Dr. Wright instituted the following experiment on a man whose ureters opened externally. Three ounces of whiskey were administered, and the urine collected by applying a test-tube to each ureter. The tubes were corked and replaced every two minutes, for the space of half an hour.

The following table represents the amount of fluid in the tubes.

1st two minutes	-	-	-	-	½ a drachm.
2d "	-	-	-	-	2 drachms.
3d*	-	-	-	-	5 drachms.
4th	-	-	-	-	1 drachm.
5th*	-	-	-	-	6 drachms.
6th*	-	-	-	-	2 drachms.
7th	-	-	-	-	½ a drachm.
8th	-	-	-	-	½ a drachm.
9th	-	-	-	-	3 drachms.
10th*	-	-	-	-	6 drachms.
11th	-	-	-	-	4 drachms.
12th	-	-	-	-	8 drachms.
13th*	-	-	-	-	7 drachms.
14th*	-	-	-	-	6 drachms.
15th*	-	-	-	-	4 drachms.

The contents of the tubes were analyzed separately, according to

¹ Journal de Pharmacie, Sept. 1843. ² On the presence of Alcohol in the Brain, 1839, p. 104.

Dr. Percy's method,¹ and in those marked with an asterisk the presence of spirit was distinctly recognised.

In another experiment upon the same individual, in which two ounces of whiskey diluted with three times its volume of water were administered, no trace of the spirit could be obtained.²

Lehmann has sought in vain for salicin, phloridzin, caffeine, theobromin, asparagin, and amygdalin.

As the modifications that these substances undergo in the organism are of extreme interest, let us see what are the most probable changes that can take place. We select salicin, by way of illustration, as a substance whose chemistry is pretty well established.

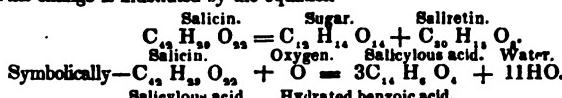
Is salicin converted in the organism into sugar and saliretin?³—a change that occurs on digesting salicin in dilute acids: or is it converted into salicylous acid and water?⁴—as occurs on treating salicin with bichromate of potash and sulphuric acid. Or, instead of salicylous acid, is hydrated benzoic acid (which is isomeric with it) produced,⁵ and the benzoic acid then converted in the ordinary manner into hippuric acid? Or does the salicin yield salicylous acid which appears to be isomorphous with, and convertible into oxide of omichmyle?⁶ Or, finally, does the salicin undergo the same changes as when oxidized by fusion with caustic potash, and become converted into salicylic, oxalic, and carbonic acids, and water?⁷ In sixteen experiments made by Lehmann with salicin in doses of 20 or 30 grains, he never detected saliretin, but always salicylous acid, which was taken up by ether with the oxide of omichmyle, and yielded the characteristic violet tint on the addition of nitrate of iron; in most of the experiments there was also a small quantity of hippuric acid, and of oxalate of lime. Similar experiments have been made by Laveran and Millon.

After taking phloridzin, Lehmann also found hippuric acid and oxalate of lime in the urine. After taking a scruple of thein at bed-

¹ Op. cit. p. 8.

² These experiments were originally recorded in my Harveian Prize Essay on the Chemistry of the Urine in Health and Disease; 1842.

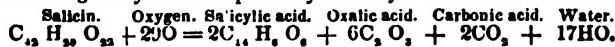
³ This change is illustrated by the equation—



⁴ Symbolically— $\text{C}_{12}\text{H}_{22}\text{O}_{12} = \text{HO.C}_6\text{H}_4\text{O}_2$.

⁵ It appears from the researches of Scharling that the oxide of omichmyle belongs to a series having a compound radical analogous to that of oil of spinea, or salicylous acid; at least he found that chloromichmyle is isomeric with chloride of salicylic acid, or chlorosalicylic acid, $\text{C}_{12}\text{H}_8\text{O}_4\text{Cl}$. Oxide of omichmyle does not produce a violet colour with nitrate of iron in the same manner as salicylous and salicylic acids; moreover, salicylous acid and salicin do not enter the urine as oxide of omichmyle, but as salicylous acid, as has been found by Lehmann in eight experiments. Scharling hints at the existence of a widely-diffused radical, which, in the vegetable kingdom, in warm climates, is the starting point of the benzoyl and cinnamyl series; in cold climates, of the salicyl compounds; and, in the animal kingdom, presents itself as omichmyle.

⁶ These changes may be thus explained symbolically:



time, no trace of it could be found in the morning urine, but the urea was considerably increased, amounting to 58.195% of the solid residue.¹ He did not remark any unpleasant symptoms, but two of his pupils, after a similar dose (obtained from coffee) experienced great excitement of the nervous and vascular systems generally, and especially of the generative organs. This is perfectly in unison with Mulder's² statement, that it produced abortion in pregnant rabbits.]

Urine of Animals.

The chemistry of the urine of animals is still in a very deficient state. I shall here give the little that is known on the subject.

The urine of carnivorous animals is, at the period of its discharge, acid, but speedily becomes alkaline, in consequence of the formation of ammonia. This observation of Hieronymi's is confirmed by Hünefeld, who found that the urine of the bear retained its acid reaction for a considerable period. Vauquelin found a large proportion of urea, but no uric acid in the urine of beasts of prey. Hünefeld also missed the uric acid, but it was detected by Hieronymi. Hieronymi carefully analyzed the urine of the lion, the tiger, and the leopard, and its composition appeared much the same in these three animals. The specific gravity of the urine of each animal varied between 1059 and 1076. It was clear, of a bright yellow colour, had a pungent disagreeable odour, an acid reaction, and a nauseous bitter taste; after standing for a short time, it became alkaline. On collecting and evaporating the urine, there was a coagulation of some white flocculent matter; and as the concentration increased, the greater part of the urea began to separate in a crystalline form. The mixed urine of these three animals gave the following result:

Water	-	-	-	-	846.00
Solid constituents	-	-	-	-	154.00
Urea, alcohol-extract, and free lactic acid	-	-	-	-	132.20
Uric acid	-	-	-	-	0.22
Vesical mucus	-	-	-	-	5.10
Sulphate of potash	-	-	-	-	1.22
Chloride of ammonium, and a little chloride of sodium	-	-	-	-	1.16
Earthy phosphates	-	-	-	-	1.76
Phosphates of soda and potash	-	-	-	-	8.02
Phosphate of ammonia	-	-	-	-	1.02
Lactate of potash	-	-	-	-	3.30

The urine of herbivorous animals likewise contains a large quantity of urea, but no uric acid,³ there being in its place hippuric acid. The urine of the horse was analyzed by Fourcroy and Vauquelin: they describe it as of a yellow colour, often turbid, of an unpleasant smell, and a saltish bitter taste. When allowed to rest, a quantity of the carbonates of lime and magnesia was deposited; it had an alkaline

¹ Lehrbuch der physiolog. Chemie, vol. 1, p. 97.

² Natuur en Scheikundig Archief, 1839, p. 458.

³ [Traces of uric acid have been occasionally detected by Fownes and other chemists, in the urine of the graminivora. See p. 54.]

reaction, frothed on the addition of an acid, and had a specific gravity of from 1030 to 1050. 1000 parts contained:

Water	-	-	-	-	940-0
Solid constituents	-	-	-	-	60-0
Urea	-	-	-	-	7-0
Hippurate of soda	-	-	-	-	24-0(!!)
Chloride of potassium	-	-	-	-	9-0
Carbonate of soda	-	-	-	-	9-0
Carbonate of lime	-	-	-	-	11-0

This analysis probably requires further confirmation. I found a large amount of urea in the urine of a horse suffering from ozæna; for from 1000 parts I obtained 50 of urea; and after the horse had fasted for four days, I still found 24-1. In the urine of another horse, the solid constituents amounted to 10-7% of the urine, and the urea to 5-06%, or about one half of the solid residue.

From my own observations, I should say that the urine of horses is generally of a straw colour, is at first acid, but soon becomes ammoniacal, and then emits the peculiar penetrating odour which is doubtless caused by the formation of a volatile fatty acid, although I was unable to isolate it. The urine, after it has become alkaline, is often so tenacious and viscid that it can be drawn up in long threads. The microscopic examination of the urine of the horse exhibits a great number of rounded corpuscles, from the size of mucus-corpuscles to four times that size, which burst upon pressure of the glass slips between which the fluid is examined. Fourcroy and Vauquelin, after evaporating the urine of the horse, separating the urea as a nitrate, and neutralizing the acid by an alkali, found a small quantity of reddish fat, which volatilizes over the water-bath, and is considered to be the cause of the smell and colour of the urine.

[The urine of the horse has been recently analyzed by Von Bibra¹ and Boussingault.

In two analyses of the urine of the same horse, made at different periods, Von Bibra found:

			1.	2.
Water	-	-	885-09	912-84
Solid constituents	-	-	114-91	87-10
Urea	-	-	12-44	8-36
Hippuric acid	-	-	12-60	1-23
Water-extract	-	-	21-32	19-25
Alcohol-extract	-	-	25-50	18-26
Mucus	-	-	0-05	0-06
Salts soluble in water	-	-	23-40	40-00
Salts insoluble in water	-	-	18-80	

On two occasions the individual salts were determined, and it was found that in 100 parts of the saline residue there were:

			1.	2.
Carbonate of lime	-	-	12-50	31-00
Carbonate of magnesia	-	-	9-46	13-07
Carbonate of potash	-	-	46-09	40-33
Carbonate of soda	-	-	10-33	

¹ Annalen der Chemie und Pharmacie, 1845, No. 1.

Sulphate of potash	-	-	13.04	9.02
Chloride of sodium	-	-	6.94	5.60
Silica	:	:	0.66 }	
Loss	:	:	1.09 }	0.98

Traces of iron were always observed, but he could never ascertain the presence of fluorine. The mean specific gravity resulting from numerous observations was 1045. The horses, in these cases, were used for agricultural purposes, and fed on hay and oats. The prevailing opinion that, by excessive work, the hippuric is replaced by benzoic acid, is stated by Von Bibra to be incorrect. Benzoic acid was scarcely ever observed, and, when present, was only recognisable under the microscope. The hippuric acid varied in different analyses from 15 to 5, or even less in 1000 parts of urine. The secretion was always alkaline, and in a few minutes deposited a sediment, consisting (as seen under the microscope) of compact vesicles. The deposit consisted of the carbonates of lime and magnesia, with an organic compound that could not be removed by the most careful washing. In three analyses there were found:

Carbonate of lime	-	80.9	87.2	87.5
Carbonate of magnesia	-	12.1	7.5	8.2
Organic matter	-	7.0	5.3	4.3
	<hr/>	100.0	100.0	100.0

Boussingault¹ has likewise analyzed the urine of a horse feeding on trefoil and vetches. It was very alkaline, had a specific gravity of 1037.3, and contained in 1000 parts :

Water and indeterminate matters	-	910.76
Urea	-	31.00
Hippurate of potash	-	4.74
Lactate of potash	-	11.28
Lactate of soda	-	8.81
Bicarbonate of potash	-	15.50
Carbonate of lime	-	10.68
Carbonate of magnesia	-	4.16
Sulphate of potash	-	1.18
Chloride of sodium	-	0.74
Silica	-	1.01
Phosphates	-	absent.

As several chemists have noticed, amongst the constituents of the urine of the herbivora, a red oil on which the colour and odour of the secretion are dependent, Boussingault endeavoured to isolate it. He distilled upwards of 26 gallons at a single experiment, but did not obtain a trace of the oil, a colourless fluid passing over which evolved the peculiar odour of horses' urine: hence he concluded that the odorous principle is a volatile acid. The only means by which any thing like a red oil can be obtained consists in carrying on the distillation to dryness, in which case an oily substance is obtained, analogous to, if not identical with some of the products of decomposition of the alkaline hippurates.]

Horses are not unfrequently subject to a disease which corresponds

¹ Annal de Chimie et de Physique, Septembre, 1845.

with diabetes insipidus, or hyperdiuresis, in man: it has also been observed in sheep and cattle.

The following analysis of the urine of cattle was made by Sprenzel: 1000 parts contained:

Water	-	-	-	926-24
Solid constituents	-	-	-	73-76
Urea	-	-	-	40-00
Albumen	-	-	-	0-10
Mucus	-	-	-	1-90
Benzoinic acid	-	-	-	0-90
Lactic acid	-	-	-	5-16
Carbonic acid	-	-	-	2-50
Potash	-	-	-	6-64
Soda	-	-	-	5-64
Silica	-	-	-	0-36
Alumina	-	-	-	0-04
Oxide of manganese	-	-	-	0-01
Lime	-	-	-	0-65
Magnesia	-	-	-	0-36
Chlorine	-	-	-	2-72
Sulphuric acid	-	-	-	4-65
Phosphorus	-	-	-	0-70

This analysis requires further confirmation.

The urine of cattle, just after it is passed, is clear and acid; it soon, however, deposits crystals of the carbonates of lime and magnesia. It contains hippurate of soda, and a larger proportion of urea than is found in human urine.

[The urine of oxen employed for agricultural purposes was analyzed by Von Bibra. The specific gravity varied from 1040 to 1032. The urine was of a dark yellow colour, perfectly clear, and of a peculiar odour.

The following analyses were made with the urine of the same animal at different times:

		1.	2.
Water	-	912-01	923-11
Solid constituents	-	87-99	76-89
Urea	-	19-76	10-21
Hippuric acid	-	5-65	12-00
Mucus	-	0-07	0-06
Alcohol-extract	-	14-21	10-20
Water-extract	-	22-48	16-43
Soluble salts	-	24-42	26-77
Insoluble salts	-	1-50	2-23

The saline residue contained:

Carbonate of lime	-	-	-	1-07
Carbonate of magnesia	-	-	-	6-93
Carbonate of potash	-	-	-	77-28
Sulphate of potash	-	-	-	13-30
Chloride of sodium	-	-	-	0-30
Silica	-	-	-	0-35
Traces of iron, and loss	-	-	-	0-77
				<hr/> 100-00

Although these salts are liable to considerable quantitative variations, (for instance, Von Bibra, in two analyses, found 14-22 and 16%

of chloride of sodium,) yet, as a general rule, the urine of oxen contains more alkaline and less earthy carbonates than the urine of horses.

The urea and hippuric acid varied extremely in different analyses. The food of the oxen consisted of fresh clover and a little hay.

Boussingault found that the urine of a cow feeding on aftermath and potatoes, effervesced briskly on the addition of an acid, and deposited numerous crystals of hippuric acid. Its specific gravity was 1040, and it contained in 1000 parts:

Water and indeterminate matters	-	921-32
Urea	-	18-48
Hippurate of potash	-	16-51
Lactate of potash	-	17-16
Bicarbonate of potash	-	16-12
Carbonate of magnesia	-	4-74
Carbonate of lime	-	0-55
Sulphate of potash	-	3-60
Chloride of sodium	-	1-52
Silica	-	traces
Phosphoric acid	-	[absent]

Vogel found the urine of the rhinoceros turbid, and having an odour like that of crushed ants. It grew darker after exposure to the air, and became covered with a film of carbonate of lime; it effervesced on the addition of acids. As it cleared, it deposited a yellow sediment composed of earthy phosphates with a little peroxide of iron and silica, which amounted to $2\frac{1}{2}$ % of the weight of the urine. It then remained of a dark yellow colour, and formed, on evaporation, a new sediment of carbonates of lime and magnesia, which were previously held in solution as bicarbonates. On evaporating the urine to two thirds of its volume, and then treating it with hydrochloric acid, a precipitation of hippuric acid took place, amounting to 0-45% of the weight of the urine. The urine also contained urea and the ordinary salts.

Vogel found the urine of the elephant turbid from the presence of carbonates of lime and magnesia in suspension; it contained a larger amount of urea than the urine of the rhinoceros, but, on the other hand, was devoid of hippuric acid. Brandes, however, detected the latter constituent, partly combined with an alkali and partly with urea.

In the urine of the camel, Chevreul found a large quantity of urea, but no uric acid; it contained, however, chloride of sodium, hippurate of soda, carbonate of soda, sulphate of potash together with a little sulphate of soda, carbonate of ammonia, and a trace of peroxide of iron: no phosphates were found in it. On mixing it with sulphuric, nitric, or hydrochloric acid, the urine became red,—a property due to its containing a volatile oil, to which, moreover, it owes its odour.

The urine of the pig has been analyzed by Lassaigne. He describes it as being of a pale yellow colour, clear and transparent, and containing urea, sulphates of potash and soda, chlorides of potassium, sodium, and ammonium, and traces of carbonate and sulphate of lime. Van Setten¹ has communicated a special analysis of the

¹ Natuur en Scheidekundig Archiv. Deel 2.

urine of a pig. It was yellow, almost inodorous, and had a specific gravity of 1003.

There were contained in 1000 parts:

Water	-	-	-	-	990.028
Solid constituents	-	-	-	-	9.972
Urea	-	-	-	-	0.750
Uric acid	-	-	-	-	0.195
Water-extract	-	-	-	-	1.708
Alcohol-extract	-	-	-	-	1.105
Resinous matter	-	-	-	-	0.425
Albumen and mucus	-	-	-	-	0.721
Lactic acid	-	-	-	-	0.490
Stearin	-	-	-	-	0.092
Sugar	-	-	-	-	0.375
Phosphate of soda	-	-	-	-	1.376
Sulphate of potash, chlorides of sodium & potassium	-	-	-	-	2.075
Sulphates of lime and magnesia	-	-	-	-	0.425
Sulphate of ammonia	-	-	-	-	0.196
Chloride of ammonium	-	-	-	-	0.010

[The urine taken from the bladders of pigs immediately after they were killed is described by Von Bibra as clear, nearly devoid of odour, alkaline, and having a specific gravity of 1012 to 1010. In two cases in which he analyzed it he found in 1000 parts:

Water	-	-	1.	2.
Solid constituents	-	-	981.96	982.57
Urea	-	-	18.04	17.43
Alcohol-extract	-	-	2.73	2.97
Water-extract	-	-	3.87	3.99
Mucus	-	-	1.42	1.12
Soluble salts	-	-	0.05	0.07
Insoluble salts	-	-	9.09	8.04
			0.88	0.80

The salts in the first of these analyses consisted of:

Chloride of sodium and a little chloride of potassium	53.1
Sulphate of soda	7.0
Carbonate of potash	12.1
Phosphate of soda	19.0
Phosphates of lime and magnesia, with traces of silica and iron	8.8
	100.0

In both the above analyses he searched in vain for hippuric or benzoic acid in three ounces of the fluid.

In two other analyses he obtained microscopic crystals of hippuric acid on the evaporation of the ethereal solution. He never detected even a trace of uric acid, which, considering the mixed nature of the food of these animals, is extraordinary.

Boussingault analyzed the urine of a pig feeding on potatoes and water slightly impregnated with salt. The urine was alkaline, very limpid, and of an extremely pale yellow colour. Its specific gravity was 1013.6.

It contained in 1000 parts:

Water and indeterminate organic matter	979.14
Urea	4.90
Bicarbonate of potash	10.74
Carbonate of magnesia	0.37

Carbonate of lime	-	-	-	traces
Sulphate of potash	-	-	-	1.93
Phosphate of potash	-	-	-	1.02
Chloride of sodium	-	-	-	1.23
Alkaline lactates	-	-	-	undetermined
Hippuric acid ¹	-	-	-	absent
Silica	-	-	-	0.07

The urine of the goat has been analyzed by Von Bibra. The animals from whom the fluid was obtained were confined in a stable and poorly fed, getting sour hay, &c. The urine was clear, of a peculiar but pungent odour, and alkaline. The specific gravity was generally 1008 or 1009. In two instances it contained in 1000 parts:

		1.	2.
Water	-	980.07	983.99
Solid residue	-	19.93	16.01
Urea	-	3.78	0.76
Hippuric acid	-	1.25	0.88
Alcohol-extract	-	4.54	4.66
Water-extract	-	1.00	0.56
Mucus	-	0.06	0.05
Soluble salts	-	8.50	8.70
Insoluble salts	-	0.80	0.40

The ash consisted of:

Carbonate of magnesia with a little carbonate of lime	7.3
Sulphate of soda	25.0
Chloride of sodium	14.7
Carbonate of soda with a little carbonate of potash	53.0
	<hr/>
	100.0

Here we remark, as in the urine of oxen, a considerable excess of the alkaline carbonates over the alkaline earths. The hippuric acid seemed very variable, sometimes equalling the urea in amount.]

Vauquelin analyzed the urine of the beaver. He found in it the bicarbonates of lime and magnesia, and hippurate of soda, but no phosphates or uric acid. He also detected the undecomposed colouring matter of the bark of the willow (the ordinary food of the beaver) in the urine; for he found that a piece of cloth which had been previously saturated with alum, took up the same colour from soaking in the urine as from lying in a decoction of the aforesaid bark.

The urine of rabbits and guinea-pigs is much the same: it has an alkaline reaction, froths on the addition of an acid, and, when exposed to the air, throws down a sediment of carbonate of lime: it contains urea and the salts which are generally met with in the urine of the herbivora.

[The urine of the hare has been examined on two occasions by Von Bibra. The first analysis was made in December. By external pressure on the region of the bladder he was enabled to collect about three pints from seven or eight hares. This was divided into two portions, one of which was evaporated and incinerated, the other

¹ Thinking that the absence of hippuric acid might be dependent on the diet, Boussingault mixed green trefoil with the potatoes: the result was, however, still the same.

tested for hippuric acid, which was found to be present in small quantity, forming 0.007% of the urine.

The ash contained:

Chloride of sodium with a little chloride of potassium	7.12
Sulphate of soda	-
Carbonate of soda	-
Phosphate of soda	-
Phosphates of lime and magnesia	-
	13.17
	100.00

The urine was turbid and alkaline, depositing a white sediment of minute globules, much smaller than those occurring in the urine of the horse, and consisting, for the most part, of phosphate of magnesia. The urine similarly obtained in the month of June had a faint alkaline reaction, and, in the course of six hours, crystals of ammoniacomagnesian phosphate were observed on the surface. Its specific gravity was 1050, and it contained in 1000 parts:

Water	-	-	-	-	912.86
Solid constituents	-	-	-	-	87.14
Urea	-	-	-	-	8.54
Hippuric acid	-	-	-	-	microscopic crystals
Alcohol-extract	-	-	-	-	9.58
Water-extract	-	-	-	-	32.68
Soluble salts	-	-	-	-	23.70
Insoluble salts	-	-	-	-	12.64

The ash consisted of:

Chloride of sodium with a little chloride of potassium	22.49
Sulphate of soda	-
Carbonate of soda	-
Phosphate of soda	-
Phosphate of lime	-
Phosphate of magnesia	-
	22.42
	100.00

The difference in the amount of earthy phosphates in these analyses is easily accounted for when we consider the different nature of the food in winter and summer.

Von Bibra obtained a minute quantity of a substance closely allied to humic acid in most of his analyses of the urine of the herbivora.]

The urine of birds, which is discharged from the cloaca as a white pulpy mass and soon hardens when exposed to the air, is remarkable for the large quantity of urate of ammonia which it contains. The urine of birds of prey contains urea, and a peculiar green colouring matter which is not found in the urine of graminivorous birds.

Vauquelin and Fourcroy found that, in the ostrich, the uric acid amounted to one sixtieth of the weight of the urine; there were also present sulphates of potash and lime, chloride of ammonium, an oily substance, a peculiar animal matter, and probably acetic acid. The urine of the parrot is, according to J. Davy, very similar to that of serpents.

The urine of serpents is excreted as a white, pultaceous, earthy mass, which soon stiffens when exposed to the air. It is composed,

for the most part, of uric acid in combination with potash, soda, and ammonia, together with a little phosphate of lime. It contains no urea, since, upon digesting it in alcohol, a yellow extractive matter is taken up, in which no crystals of urea can be detected.

On the other hand, Berzelius directs our attention to the circumstance that Cap and Henry have obtained urea from that source, after having saturated the uric acid with hydrated baryta.

[For an analysis of the urine of the rattle-snake, see p. 54, note.]

The urine of the bull-frog (*rana taurina*) consists, according to J. Davy, of a fluid of specific gravity of 1003, which contains urea, chloride of sodium, and a little phosphate of lime in solution. The urine of *bubo fuscus* had a specific gravity of 1008; it contained a larger proportion of urea than the urine of the frog, together with chloride of sodium and phosphate of lime. In the urine of *testudo nigra*, which was examined by Magnus and J. Müller, there was no uric acid; on the other hand, there was 0·1 $\frac{1}{2}$ of urea, with a brown colouring matter which was soluble in water, spirit, potash, and hydrochloric acid.

[The urine of a land-tortoise (*testudo tabulata*), which had been kept without food for some months, has been recently examined by Marchand.¹ It had a faintly acid reaction, and resembled pus in appearance. He collected 1337 grains, consisting of:

			Or in 1000 parts.
Water	-	-	1271 950·64
Solid constituents	-	-	66 49·36
Urea	-	-	85 6·40
Uric acid	-	-	23·0 17·25
Hippuric acid	-	-	none
Salts and indeterminate organic matter	-	-	345 25·70

A small quantity of brown liquid fat, with a strong urinous odour, was taken up by ether.]

CHAPTER VIII.

THE SECRETIONS OF THE LACHRYMAL, MEIBOMIAN, AND CERUMINOUS GLANDS.

The Tears.

The glandulae lachrymales are two conglomerate acinous glands, which secrete a limpid fluid, containing a very small proportion of solid constituents, and forming the tears. They are for the purpose of preserving the cornea of the eye in a state of moisture, and their secretion is much increased by intense feelings either of joy or grief.

The tears have not yet been subjected to an accurate analysis,

¹ Erdmann und Marchand's Journ. 1845, iv. 4.

partly perhaps from the subject being one of little interest in a scientific point, and partly from the difficulty of obtaining a sufficient quantity.

When examined under the microscope, the tears exhibit a small quantity of pavement epithelium and a few mucus-corpuscles swimming in a clear fluid. They have a slightly saline taste, (much like that of the perspiration that exudes from the forehead,) and change red litmus-paper to a pale blue.

The only chemical examination of the tears that can be depended on is that of Fourcroy and Vauquelin, who assert that they resemble in their constitution the aqueous humour of the eye. The solid constituents amount to only 1%, and consist principally of chloride of sodium and of a yellow extractive matter which is not perfectly soluble in water: it is not improbable that the insoluble portion arises from the fatty-mucous secretion of the Meibomian glands. The mucus also into which, according to those chemists, the extractive matter of the tears is converted previously to its being perfectly dried, may be, as Berzelius conjectures, the secretion of the Meibomian glands. With regard to this latter secretion,—the gummy secretion of the eyes, we know even less than of the tears: it seems to consist principally of a mucous matter and of fat.

Cerumen.

The glandulæ ceruminosæ, which are situated in the external skin of the meatus auditorius externus, secrete the ear-wax (cerumen,) a peculiar salve-like matter, which is thrown out as a yellowish milk.

If a small portion of ear-wax is pressed between two slips of glass and observed under the microscope, we shall find a quantity of variously-grouped lamellæ lying in a tolerably homogeneous yellow mass. In these lamellæ, the practised observer will easily recognise pavement epithelium. On mixing the ear-wax with water, which may be readily done, a sort of yellowish milk is obtained, in which, with a microscope, we may observe colourless fat-vesicles, epithelium-scales, and sometimes rhombic crystals, very like cholesterol. The yellow colour of the cerumen does not belong to the fat, but to the matter which is soluble in water. Berzelius has made the following observations on the cerumen. Ether takes up fat from the mass which swells in it, and becomes as soft as goose-grease; it has not an acid reaction, consists of stearin and olein, and contains a substance which, after saponification, gives off a strong smell of sweat. The fatty acids which are liberated on the addition of hydrochloric acid melt at 104°. After the fat has been removed, alcohol takes up a yellow substance from the ear-wax, which, on evaporation of the alcohol, is left as a glossy matter, perfectly soluble in water, and of a very bitter taste. It may be entirely thrown down from its aqueous solution by the neutral acetate of lead and by chloride of tin; on the other hand, nitrate of silver does not even render it turbid; hence

there can be no chlorides present. Upon incinerating this mass, there remains an ash, which consists of the carbonates of potash and lime. The portion not dissolved by alcohol yields to water a small amount of yellowish matter, which is very similar to the soluble matter obtained in a similar manner from the other fluids of the animal body, and has a piquant taste; but it is distinguished by the circumstance that neither lime-water, basic acetate of lead, bichloride of mercury, nor tannic acid precipitate it.

The portion of the ear-wax which is insoluble in ether, alcohol, and water, is, next to the fat, the largest: acetic acid causes it to swell, and only takes up a very small portion of an albuminous matter. The residue (consisting evidently of nothing but epithelium-cells) is partly soluble in free potash, from which it cannot be again precipitated by acetic acid; ferrocyanide of potassium causes no precipitate in the acid solution, but infusion of galls a very copious one. Another portion of the residue, when heated with a concentrated solution of potash, enters into combinations which are not soluble in that fluid, but which are soluble in water, similar to what is observed in the urine.

This investigation shows that the ear-wax is an emulsive compound, which contains a soft fat, albumen, a peculiar extractive bitter matter, epithelium-scales, lactate of lime, and an alkaline lactate, but no chlorides and no phosphates soluble in water.

CHAPTER IX.

SECRECTIONS AND FLUIDS OF THE GENERATIVE ORGANS.

1. *Secretions of the male generative organs.*

SEmen.

THE seminal fluid which is formed in the testicles and is conveyed along the vas deferens, is a thick, whitish, glutinous mass possessing a peculiar odour, and when examined under the microscope is found to be composed of a clear fluid, in which an immense number of minute caudate molecules, the spermatozoa, appear to be moving about at will. (Fig. 33.) In addition to the spermatozoa, seminal granules are likewise to be seen, which, according to Wagner, are rounded, fine granular corpuscles of $3\frac{1}{10}$ — $4\frac{1}{6}$ of a line in diameter, and a few epithelium-scales.

The spermatozoa occur in the semen of nearly all animals: they are elliptic in man, but assume various forms in different classes of animals.

The chemical analysis of the semen, although not an uninteresting subject, seems little calculated to throw any light upon the remark-

ble process that is recognised in the term impregnation. We cannot even form any conjecture regarding the connexion and the reciprocal effect that must take place between the fructifying semen and the ovum which is to be fructified; and although we cannot doubt that there are certain chemical processes going on, since the act of impregnation is succeeded by a change not only of form but of matter, we have as yet but little prospect of investigating the subject successfully, in consequence of the insufficiency of our resources.

The seminal fluid at the period of emission is somewhat turbid, and is mixed with the mucous secretion of the prostate, from which it cannot be separated. It has not always the same consistence, and the longer it remains in the vesiculae seminales, the more consistent it becomes.

The investigations of Vauquelin, Jordan, and John have elicited the following results, which, however, do not sufficiently explain its chemical relations. When the seminal fluid has been allowed to rest for some time, it becomes clear, more fluid, transparent, and almost entirely soluble in water; if, on the contrary, it is at once dropped into water it sinks, and instead of perfectly dissolving, it coagulates in threads, in the same manner as if it had been treated with alcohol. This coagulated matter is readily soluble in acetic acid, and the solution gives a copious precipitate on the addition of ferrocyanide of potassium.

- On allowing the coagulum to remain in water, it gradually dissolves therein, leaving a residue of a few flocculi. The solution, if rapidly evaporated, gives off the peculiar odour of semen, and leaves a clear glossy residue, which is opaque in water, and only partially dissolves in that fluid. From the portion which is insoluble in water, alcohol takes up extractive matter; and the portion insoluble in alcohol dissolves in boiling water, leaving a mucous residue: the solution is precipitable by acetate of lead, chloride of tin, bichloride of mercury, nitrate of silver, and infusion of galls.

In semen which had stood for some time, Vauquelin found four-sided prisms arranged in stellar groups, and terminating in long four-sided pyramids, which Berzelius considers to have been ammoniacomagnesian phosphate. If the semen is allowed to evaporate it becomes covered with a film, in which white points may be observed, which are supposed by Vauquelin to be composed, as well as the before-mentioned prisms, of phosphate of lime. When the whole of the water has been removed by evaporation, there remains a yellow, transparent, elastic mass, which amounts to 10% of the weight of the semen.

Vauquelin, moreover, states that fresh semen is soluble in all acids, from which it cannot be precipitated by alkalies, and conversely, that it is soluble in the alkalies, from which it is not precipitable by acids: chlorine-water, however, coagulates it to such a degree as to render it insoluble in water or acids. If the semen at the moment of emission is allowed to fall into alcohol, and to remain in it for some

time, it coagulates thoroughly, becomes opalescent, and resembles a long thread: it is now incapacitated from returning to a state of solution like fresh semen, but remains on being dried, fibrous, snow-white, and opaque. It gradually softens in water, but even at the boiling point only a very small portion dissolves in that fluid; it swells, however, like mucus. If the water in which it has been boiled is evaporated, a white matter remains, which is partly soluble in cold, partly in boiling water, and the solution is freely precipitable by tannic acid. That portion of the semen, after coagulation by alcohol, which is not soluble in boiling water, will also resist the action of dilute solution of potash at a moderate temperature; it will, however, dissolve on being heated with a concentrated solution of caustic potash, and it cannot be again precipitated from this solution by acetic acid. With concentrated sulphuric acid it forms a yellow fluid, without the application of heat; on the addition of water it is precipitated with a white colour, and the precipitate is not soluble in an excess of water.

With acetic acid the coagulum becomes gelatinous and transparent; on being diluted and warmed it dissolves, but does not form a perfectly clear fluid: this is only rendered turbid by ferrocyanide of potassium, is not precipitated by bichloride of mercury or carbonate of ammonia, but by tannic acid is thrown down in light floccules, which continue for a long time in suspension.

From these researches Berzelius concludes that the semen contains a peculiar matter which may be obtained in two separate states depending upon whether it be projected into water or alcohol. When coagulated by alcohol it has an external resemblance to fibrin, and, moreover, like that substance, it can be precipitated from its acetic-acid solution by ferrocyanide of potassium: on the other hand, it differs from it in its solubility in nitric acid, and in its power of resisting the soluble action of a cold solution of potash.

On heating the residue of the semen it becomes yellow, emits an odour of burnt horn, gives off a considerable quantity of ammonia, and leaves a carbonaceous mass which is not easy of incineration, and contains carbonate of soda, chloride of sodium, and phosphates of lime and magnesia. Vauquelin assigns the following composition to the seminal fluid.

In 100 parts there are—

Peculiar extractive matter	:	:	:	:	6
Phosphate of lime	:	:	:	:	3
Soda	:	:	:	:	1
Water	:	:	:	:	90

According to John, the seminal fluid contains a substance resembling mucus, with small quantities of a peculiar form of albumen, of a substance slightly soluble in ether, of soda, phosphate of lime, chloride of sodium, sulphur, and a volatile odorous principle.

The prostatic fluid which mixes with the semen of the male, at the moment of emission, has never yet been procured in sufficient

quantity for analysis: it forms an almost clear fluid, which may be drawn out in threads.

2. *Secretions of the female generative organs.*

LIQUOR AMNII.

The liquor amnii surrounds the foetus: at the period of delivery the membranes which contain it give way, and it escapes externally. Although it has been submitted to numerous analyses, its nature, even now, is not clearly understood. Human liquor amnii is turbid, and holds in suspension flocculi of caseous matter, arising from the vernix caseosa with which the foetus is covered. Its specific gravity is 1005, and it contains from $1\cdot2\frac{1}{2}$ to $1\cdot6\frac{1}{2}$ of solid constituents; but according to Fromherz and Gugert, as much as $3\frac{1}{2}$. It has a very decided alkaline reaction, but the indications of this reaction disappear when the test paper is dried; it is consequently dependent on free ammonia.

Alcohol took up extractive matter from the residue of the liquor amnii, and there remained, according to Fromherz and Gugert, a quantity of albumen, salivary matter (ptyalin,) and casein.

When evaporated to the consistence of a syrup, and treated with hydrochloric acid, acid flocculi separated themselves, which were recognised, after a careful analysis, as benzoic acid. Berzelius, however, supposes that it might have been hippuric acid. After the fluid had been filtered, and the above matter removed, nitric acid was added and the mixture submitted to the action of cold. Verrucose crystals then separated themselves, which were assumed to be composed of nitrate of urea, without being further analyzed.

The salts of the liquor amnii are described as consisting of chloride of sodium in large quantity, phosphate, sulphate, and carbonate of soda, sulphate of lime, and a small amount of potash-salts.

The analyses of Voigt, which were made with the liquor amnii of women who had died in various stages of pregnancy, give discordant results, probably as Berzelius supposes from the circumstance of the fluid at the full time being different from what it was in the early stages of pregnancy. The liquor amnii at the fourth month was not turbid, had an insipid taste, a specific gravity of 1018·2, a neutral reaction, frothed upon being shaken, coagulated on boiling, was precipitated by bichloride of mercury and tannic acid, and less copiously by perchloride of iron and acetate of lead. After coagulation by boiling, the fluid which had been cleared by filtration, was strongly precipitable by nitric acid, while it was very little affected by chloride of barium, lime water, ammonia, or oxalate of ammonia. Perchloride of iron, and chloride of platinum, produced no effect upon it.

The liquor amnii at the sixth month was turbid, yellowish, viscid, had a specific gravity of 1009·2; when heated to the boiling point gave a mucous coagulum which could not be separated by filtration,

and its behaviour towards reagents was the same as in the former case. As to casein, ptyalin, urea, benzoic and hippuric acids, Voigt was as unable to find them as carbonate of ammonia or sulphuret of ammonium, and he conceives that at least some of these substances may arise from the foetal urine which becomes mixed with the liquor amnii previous to delivery. Voigt's view of the composition of the liquor amnii is as follows:

	At the 4th month.	At the 6th month.
Water	979.45	980.29
Alcohol-extract and lactate of soda	3.69	0.34
Albumen	10.77	6.67
Chloride of sodium	5.95	2.40
Sulphate and phosphate of lime	0.14	0.30

[Four specimens of liquor amnii examined by Dr. Rees¹, extracted from four individuals in the 7½ month of pregnancy, contained the same constituents. The specific gravity varied from 1008.6 to 1007. They were alkaline, contained urea, and the same salts as occur in the blood. One specimen contained:

Water	-	-	-	-	984.98
Solid constituents	-	-	-	-	15.02
Albumen with traces of fatty matter	-	-	-	-	1.80
Extract soluble in water	{ Salts	-	-	2.80	}
	{ Organic matter, chiefly albumen	-	3.22		6.02
Do. soluble in water and alcohol	{ Salts	-	2.80		
	{ Organic matter, chiefly	-		4.4	7.20
	lactic acid and urea	-			

The caseous matter floating in the liquid contained cholesterol.

The liquor amnii at the full time has been recently analyzed by Mack,² who obtained two specimens for examination from Dr. Mikschik. The fluid in both cases was perfectly pure, the membranes being ruptured as they projected from the external organs.

The quantity of the fluid in the first case amounted to a little more than an ounce and a half; it was turbid, with white flocculi of vernix caseosa in suspension; it had a sickly odour, and a faintly saline taste. Under the microscope there were seen isolated mucus-corpuscles, with pavement and ciliated epithelium. The specific gravity was 1006.3, and the reaction faintly alkaline. The fluid coagulated slightly on heating, and became covered with a thin membrane during evaporation.

The amount of fluid obtained in the second instance was slightly above two ounces; the specific gravity was 1004.7; the reaction alkaline; and the other physical characters the same as in the former case. In 1000 parts there were contained:

		1.	2.
Water	-	985.147	988.123
Solid constituents	-	14.853	11.877
Fat	-	1.250	0.132
Alcohol-extract	-	5.251	4.752
Water-extract	-	4.651	4.352

¹ Phil. Mag. (3d series) vol. 13, p. 395.

² Heller's Archiv für physiol. und pathol. Chemie und Mikroskopie, vol. 2, p. 218.

Matter insoluble in water	-	3.701	2.641
Sulphate of lime	-	1.722	1.672
Chloride of sodium and carbonate of soda	{	7.611 { 9.333	7.564 } 9.236 fixed salts.

Urea and hippuric acid were carefully, but unsuccessfully, sought for in both specimens; neither could carbonate or hydrosulphate of ammonia be detected.

It is suggested by Mack that the discrepancies in the results obtained by other chemists may be owing to their having examined the fluid mixed with blood, mucus, or urine. Two years ago he analyzed a specimen (under the superintendence of Dr. Ragsky) which contained much blood and mucus. The fluid was of a dirty yellow colour, and deposited a sediment. Under the microscope there were seen blood and mucus-corpuscles, with epithelium-cells. The specific gravity was 1011.2.

In 1000 parts there were contained:

Water	-	-	-	984.131
Solid constituents	-	-	-	15.869
Fat	-	-	-	0.4984
Alcohol-extract	-	-	-	0.8529
Water-extract	-	-	-	4.0998
Substances insoluble in water	-	-	-	104177]

Several analyses have been made of the liquor amnii of animals. A very remarkable observation on this subject was made by Prout. The liquor amnii of a cow in an early stage of pregnancy was of a yellow colour, and opaque in consequence of holding a large quantity of glittering particles in suspension; its taste was like that of fresh whey, it smelt like fresh milk, and was neutral to test paper. Upon heating it to the boiling point it coagulated; coagulation was, however, prevented by the addition of acetic acid: with chloride of barium it gave a copious precipitate. The fluid which had been boiled gave, after filtration and evaporation, crystallizable sugar of milk, from which alcohol took up a yellow extractive matter with some lactates. Berzelius remarks that the presence of sugar of milk in the liquor amnii at an early period, is of the greatest physiological interest, since it doubtless contributes to the nutrition of the foetus. Prout gives the following as the composition of 100 parts of this fluid:

Water	-	-	-	97.70
Albumen	-	-	-	0.26
Alcohol extract and lactates	-	-	-	1.66
Water-extract, salts, and sugar of milk	-	-	-	0.38

In the liquor amnii of a mare which Voigt examined, he also found no urea. It had a specific gravity of 1005.1, and left a solid residue of 1.45%, half of which was soluble in alcohol: the portion which was not soluble in it consisted of albumen, chloride of sodium, and sulphate of lime.

In the liquor amnii of a cow, which was viscid, very thick, of a yellow colour, and had a saltish taste and an alkaline reaction, Lassaigne found albumen, mucus, a yellow matter analogous to bile, chlorides of sodium and potassium, carbonate of soda, and phosphate

of lime: no extractive matters are enumerated amongst the constituents. The flocculi which are suspended in the liquor amnii of the cow are said by this chemist to be composed of albumen with 0·27 of their weight of oxalate of lime.

I have already treated of vaginal mucus, menstrual blood, and the secretion of the mammary glands; it still remains for me to offer a few remarks on the fluid of the allantois. The allantois with its enclosed fluid is absent in the human embryo: it is found, however, in many animals. It is situated above the amnion, and it is between these two membranes that the urine of the foetus collects, being conveyed there by the urachus from the urinary bladder, and constituting the fluid of the allantois.

It has several times been the object of chemical investigation; it is clear, of a brown-yellow colour, of a bitter and saltish taste, and reddens litmus paper. Its specific gravity, according to Dzondi, fluctuates between 1003 and 1029. On evaporation flocculi are precipitated, which consist of albumen and phosphate of lime. The residue left after evaporation is very slightly soluble in alcohol, which takes up a yellowish-brown acid extractive matter, and white nacreous crystals which retain their form upon mixing the residue obtained by evaporation with water, and constitute allantoin, which was first termed by Vauquelin, amniotic acid, and by Lassaigne, allantoic acid. The substances remaining in the watery solution, are chloride of sodium, alkaline lactates, a salt of ammonia, and extractive matters. From the portion insoluble in alcohol, water takes up sulphate and phosphate of soda, phosphates of lime and magnesia, and a brown extractive matter which is copiously precipitated by infusion of galls. Whether the fluid of the allantois contains urea as well as allantoin is a point not yet ascertained.¹

In speaking of the liquor amnii we mentioned that the floccules which are seen swimming in it are derived from the peculiar caseous matter, the *vernix caseosa*, which invests the foetus. I shall avail myself of this opportunity of offering a few remarks upon this substance. Upon examining this caseous investment with the microscope, I found, especially when it had been previously diluted with water, a very large quantity of pavement epithelium, numerous fat-vesicles, and some but not a great many crystals, which in part resembled cholesterolin, and in part distinctly assumed the form of ammoniaco-magnesian phosphate.

Upon examining the *vernix caseosa* by the microscope, without previously diluting it with water, indications of a large number of crystals presented themselves; they disappeared, however, on the addition of water, and I concluded that this peculiar appearance was caused by epithelium-cells.

According to Fromherz and Gugert the *vernix caseosa* consists of a mixture of fat resembling cholesterolin with coagulated albumen. Microscopic investigation at once shows that what was considered

¹ See p. 56.

by these observers as albumen, was at any rate for the most part epithelium, and that a considerable quantity of fluid fat must be present besides cholesterol. They also state that ether takes up from the vernix caseosa a fat which crystallizes in glittering leaves, which does not admit of saponification, and does not melt in boiling water. Cold water takes up a little of the portion which is insoluble in ether, and boiling water takes up a yellowish substance with an alkaline reaction, which they regarded as ptyalin, but which Berzelius conceives to be most likely albuminate of soda. The residue is evidently epithelium, since it is insoluble in a cold, but soluble in a boiling solution of potash.

[The most recent observations on the vernix caseosa are those of Dr. Davy.¹ He states "that its specific gravity (after the air that is entangled in it is removed) is 1003.9. It is very retentive of water. It required ten hours' exposure over the steam-bath, to expel from eight grains the whole of the water belonging to it, when it was reduced to 1.77 grain. A specimen of great purity taken from a healthy infant immediately after birth was found to consist of:

Water	-	-	-	-	-	77.87
Olein	-	-	-	-	-	5.75
Margarin	-	-	-	-	-	3.13
Epithelium scales	-	-	-	-	-	13.25
						100.00

"A portion of the same was incinerated: it burned with a bright flame and left a very small quantity of white ash, hardly $\frac{1}{10}$ th of a grain, although 40 grains was the quantity consumed, weighed before drying. This ash, in a drop of dilute muriatic acid, dissolved, emitting a distinct smell of sulphuretted hydrogen; and the solution was clouded by adding a little ammonia, indicating the presence of a minute portion of phosphate of lime and sulphur—the latter in union probably with lime or potash."]

CHAPTER X.

THE INTESTINAL EXCRETIONS.

THAT portion of the food which is not taken up by the absorbents which are every where distributed between the stomach and the large intestine is again discharged from the system as fæces.

The fæces must materially vary with the species of food that is taken, and with the energy of the digestive powers. When we see that many men are kept in a better and more desirable condition on a very small quantity of food, than others who take a large amount of

¹ Medico-chir. Trans. 1844, p. 193.

nutritious aliment, we must necessarily conclude that in the former case every thing which could possibly serve for nutrition was extracted and suitably employed, while in the latter we must suppose that only a small portion of nutritive matter was taken up from the large quantity of food, and that the greater portion was discharged with the faeces. In accordance with what I briefly stated respecting the fluid secretions of the chylopoietic viscera in relation to the process of digestion, it follows that after food has been taken the faeces must contain (1) that portion of the food which has not been absorbed, and (2) the addition which is received in the form of secretion from the intestinal canal and its appendages, between the mouth and the anus. These consequently are, those substances which are altogether insoluble in the digestive fluids, as, for instance, vegetable fibre; those which, although capable of digestion, have from various causes not been digested, as for instance, the flesh of old animals, sinews, ligaments, fat, &c.; the bile, more or less modified, together with biliphaein and cholesterin, the mucus of the intestinal canal, and a considerable amount of salts, amongst which ammoniaco-magnesian phosphate is especially distinguished by its well-defined crystals.

The faeces of adults are, however, different from those of the foetus and the infant at the breast, as the following analyses will show.

I have made an analysis of the faeces of the foetus,—the *meconium*; it constituted a thick, glutinous greenish-black mass, had a sweetish insipid odour, and a corresponding taste: when examined with the microscope, after being diluted with water, a very large number of epithelium-cells and numerous rhombic plates, resembling crystallized cholesterin could be seen, besides a green-coloured amorphous mass which was present in considerable quantity.

A small number of minute rounded corpuscles, which upon floating about, allowed me to recognise their flattened shape, appeared to be discoloured blood-corpuscles.

Ether took up, from the dried meconium, a firm white fat,—cholesterin; alcohol took up some extractive matter with bilifellinic acid; spirit took up a substance reacting exactly like casein, together with some bilifellinic acid; finally, alcohol acidulated with sulphuric acid took up some green bile-pigment. There remained cells, mucus, and probably albumen.

100 parts of the dried meconium contained:

	Analysis 149.
Cholesterin	16·00
Extractive matter and bilifellinic acid	14·00
Casein	34·00
Bilifellinic acid and bilin	6·00
Biliverdin with bilifellinic acid	4·00
Cells, mucus, albumen	26·00

The ash of meconium consists, according to Payen, of an alkaline carbonate, and phosphate of lime.

[Dr. Davy¹ has recently examined the meconium both micro-

¹ Medico-Chirurg. Trans. 1844, p. 189.

scopically and chemically. "It may be advantageously examined by the microscope, either mixed with water or in a saturated solution of common salt, or merely compressed between two plates of glass. Using either method, its appearance is much the same,—it exhibits a confused mixture of globules, plates, and molecules.

"The globules, about 1-3000th of an inch in diameter, are very abundant, and form the principal mass of the whole. Judging from their form and size, their insolubility in water and alcohol, they may be inferred to consist chiefly of mucus.

"The plates, which are tolerably abundant, are of two kinds; one kind is of irregular form, somewhat granular, varying in size from about 1-2000th to 1-1000th of an inch in diameter, insoluble in water, alcohol, whether hot or cold, and the dilute acids and alkalies after the manner of epithelium-scales, which we believe them to be. The other kind are of a regular form, chiefly rhomboidal, of great thinness and perfect transparency, insoluble in water and acids and cold alcohol, but readily soluble in hot;—properties sufficiently indicative of cholesterin.

"The molecules vary in size from 1-8000th to 1-20,000th of an inch in diameter;—and, as they are insoluble in water, and in most part soluble in an alkaline ley, they may be considered as consisting chiefly of fatty matter. They constitute a very small part of the whole.

"Besides these ingredients admitting of being distinguished by the microscope, to which the meconium owes its thick consistency and viscid nature, there is another portion, the soluble part, with which they are imbued, and from which the mass derives its colour and taste, and probably its power of resisting putrefaction, and which seems identical with the colouring and sapid matter of bile, being soluble in water and alcohol.¹

"The specific gravity of meconium, deprived of air, exceeds that of water. It sinks in a saturated solution of common salt of the specific gravity of 1148.

"This mixture of meconium and brine affords, after standing for some time, a kind of mechanical analysis or separation of its ingredients. The mucus-globules and epithelium-scales, dyed of a dark green by the colouring matter, find their place of rest at the bottom, whilst in the supernatant fluid, slightly turbid, and of a bright greenish-yellow hue, numerous plates of cholesterin, and a smaller number of fatty globules and molecules are found suspended."

Every specimen examined by Dr. Davy, (some voided just after birth, others taken from the intestines of still-born children,) was very similar, composed chiefly of mucus-globules and epithelium-

¹ This property of meconium is remarkable. After more than three months a portion put by in a bottle containing a good deal of air, closed to prevent the drying of the substance, was found unaltered in colour, and presenting the same appearance under the microscope as when first examined; the only perceptible difference was that its upper surface was covered with a mould or mucor, like that of cheese, formed of connected globules, each about 1-5000th of an inch in diameter.

scales, and of biliary matter containing, besides the colouring and sapid matter of the bile, a small portion of cholesterin, of margarin, and olein, with a little free acid, probably the carbonic, judging from the absence of a precipitate on the addition of nitrate of silver, and from the circumstance that the redness imparted to litmus paper was removed by heat.

A specimen obtained from a healthy child immediately after birth, contained:

Water	-	-	-	72·7
Mucus and epithelium-scales	-	-	-	23·6
Cholesterin and margarin	-	-	-	0·7
Colouring and sapid matter of bile, and olein	-	-	-	3·0
<hr/>				100·0

A portion of the same meconium was incinerated. It burned, after becoming semifluid, with a bright flame, and left 69% of reddish ash, chiefly peroxide of iron and magnesia, with a trace of phosphate of lime and chloride of sodium: the magnesia seemed to be the predominant ingredient and uncombined.]

I have likewise analyzed the faeces of an infant six days old, nourished on its mother's milk. They were pultaceous, of a yellow colour, had a strong acid odour, and both smelled and tasted like sour milk. When the mass was diluted with water, I could observe through the microscope an extraordinary number of fat-vesicles; there were no epithelium-cells, but I found an amorphous consistent matter resembling coagulated albumen or casein. The proportion of fat was so large that on evaporation the whole mass became fluid. Ether took up this fat, which appeared to be more solid than butter, but contained no cholesterin, since it was perfectly saponifiable. After the removal of the fat, the faeces did not yield any extractive matter to alcohol, but gave biliverdin to alcohol acidulated with sulphuric acid. On extracting this colouring matter with ether, a considerable quantity of green fat was taken up.

100 parts of the dried faecal mass contained:

	Analysis 150.
Fat	52·00
Bile pigment with fat	16·00
Coagulated casein with mucus	18·00
Moisture and loss	14·00

No accurate analysis of the excrements of the healthy adult has been made, that I am aware of, since 1804, when Berzelius investigated the subject: I shall therefore give his results. The excrements mix very gradually with water, which they render mucous and turbid, and which is a long time clearing itself: on decanting the mixture, there remains a grayish-brown residue consisting of insoluble vegetable matter, through which a thick grayish-green fluid permeates, depositing a copious sediment when placed in a corked bottle.

The thinner supernatant portion can only be filtered with difficulty. If the fluid is very concentrated, and is at the same time

clear, it will soon be observed to become dark, a change of colour apparently due to the action of the atmosphere. When this fluid is evaporated, crystals of ammoniac-magnesian phosphate gradually form on the surface: as they were not previously apparent, we may conclude that the ammonia is subsequently produced. On extracting with alcohol the residue left after the evaporation of the water, a substance of a reddish-brown colour is taken up, while a grayish-brown matter (A) remains undissolved.

The alcoholic solution yields on evaporation a residue which forms a resinous precipitate with sulphuric acid, consisting of bilifellinic acid with an excess of bilin, which may be separated by oxide of lead into bilifellinate of lead and bilin.

On distilling the mixture with sulphuric acid we obtain a fluid which yields traces of hydrochloric but not of acetic acid: on saturating the sulphuric acid in the residue with baryta, after the separation of the biliary resin, and then evaporating, and treating the dry mass with alcohol, an extractive matter of a reddish-brown tint is taken up, which is apparently the cause of the change of colour to which we have already alluded in the concentrated aqueous solution of the fæces. This substance is soluble in alcohol and in water, is almost entirely precipitated by the salts of tin, lead, and silver, and on the addition of an acid a bright red deposit is formed. On adding a little tannic acid it is precipitated in the form of a red powder, and by an excess of that reagent, in grayish-brown flocculi.

The substance (A) which is soluble in water but not in alcohol, consists of albumen coloured brown by bile, containing, mixed with it, alkaline sulphates and phosphates, and phosphate of lime.

That portion of the fæces which is insoluble in water, and remains floating on its surface, consists of a mixture of intestinal mucus and of the substances precipitated by the bile: it is very viscid, clogs up the pores of filtering paper, and dries upon it as a glistening, brittle, and elastic coating; on being again placed in water it softens, and, especially if any free alkali is present, becomes viscid as before.

This mass is perfectly soluble in caustic potash, and may be again thrown down by the addition of an acid; the fluid then gives off an odour of bile. Ether and alcohol take up fat and biliary resin, and yield greenish extracts. The ethereal solution becomes turbid on the addition of alcohol in consequence of the precipitation of fat; the residue left after evaporation melts in boiling water, leaves spots of fat on filtering paper; and dissolves in caustic potash; hence it contains no cholesterol. The portion left after the aforesaid extractions with ether and alcohol, imparts to water a peculiar yellow matter which soon changes to a darker tint after exposure to the air; it is devoid of odour or taste, and rapidly becomes putrid. It is at first insoluble in alcohol, but it becomes soluble as decay commences; moreover when fresh it is hardly rendered turbid by the addition of infusion of galls, but is strongly precipitated by that reagent after the commencement of putrefaction. If this substance, when quite fresh,

is mixed with the solution of fat and biliary resin which we have just described, we observe a grayish-green precipitate which deposits itself as slowly as the precipitate from which these substances were originally obtained. Hence, as Berzelius remarks, we may conclude that the excrements contain an insoluble combination of the constituents of the bile, with other materials which have been added to it in the course of the digestive process.

The analysis of human faeces, sufficiently consistent to form consistent masses, yielded to Berzelius the following results in 1000 parts:

Water	-	-	-	-	-	-	733-0
Solid constituents	-	-	-	-	-	-	267-0
Bile	-	-	-	-	-	-	9-0
Albumen	-	-	-	-	-	-	9-0
Peculiar extractive matter	-	-	-	-	-	-	27-0
Salts	-	-	-	-	-	-	12-0
Insoluble residue of food	-	-	-	-	-	-	70-0
Substances added in the intestinal canal, as mucus, biliary resin, fat, a peculiar animal matter, &c.	-	-	-	-	-	-	140-0

The salts in this analysis were determined by a separate experiment: three ounces of fresh excrement were repeatedly extracted with water, and the residue obtained by evaporation was incinerated.

The ash was composed of:

Carbonate (lactate of soda)	-	-	-	35
Chloride of sodium	-	-	-	40
Sulphate of soda	-	-	-	20
Phosphate of magnesia	-	-	-	20
Phosphate of lime	-	-	-	40
				15-5

We observe that there is a considerable proportion of phosphate of magnesia, and a much larger of phosphate of lime; the former constituting 13-3% and the latter 26-6% of the salts. The comparatively large amount of phosphate of magnesia may be partly accounted for by the use of coarse bread, which contains a considerable quantity of this salt.

From dried excrements Berzelius obtained 15-0% of fixed salts, of which 10% were earthy phosphates with a trace of sulphate of lime, 0-8% carbonate of soda, an equal quantity of sulphate of soda with sulphate of potash and phosphate of soda, and 1-6% silica originating from vegetable matters. Nothing is said regarding the chlorides; they were probably not determined.

[Enderlin has instituted numerous observations on human faeces, chiefly in reference to the salts.

A. Fresh excrements of a yellowish-brown colour, a pulpy appearance, and an alkaline reaction, were dried and incinerated. The resulting ash was white, alkaline, effervesced on the addition of an acid, and contained:

Tribasic phosphate of soda (a little.)
Chloride of sodium.
Alkaline sulphates.

Phosphates of lime and magnesia (in abundance.)
 Carbonate and sulphate of lime.
 Phosphate of iron (a trace.)

b. Another portion of the same excrement was extracted with water, and the brown, alkaline solution evaporated on the water-bath.

During the process of evaporation there was formed on the surface a tenacious, yellowish-brown film, which, when removed, was speedily replaced.

a. One half of the evaporated aqueous extract was incinerated. The ash was very alkaline, effervesced briskly on the addition of an acid, and contained:

Alkaline carbonates.	Alkaline sulphates.
Alkaline phosphates.	Chloride of sodium and earthy phosphates.

b. The other half of the evaporated aqueous extract was treated with alcohol, which assumed a tint varying from a red to a green, and had an alkaline reaction. On evaporating the alcoholic solution, an alkaline ash was obtained, consisting, for the most part, of tribasic phosphate of soda and chloride of sodium.

The membrane and other matters not taken up by alcohol, yielded a neutral ash consisting of phosphates of lime and magnesia, with traces of chloride of sodium and alkaline phosphates.

c. The portion of excrement not taken up by water, yielded a neutral ash consisting of:

Phosphates of lime and magnesia.
Sulphate of lime.
Traces of chloride of sodium and alkaline phosphates.

With a solution of baryta, the alcoholic solution yielded a very bulky, yellowish-green precipitate; and, on the addition of basic acetate of lead, there was a considerable sediment soluble in acetic acid, decolorization of the fluid, &c; hence unchanged choleate of soda was present. The occurrence of this constituent was, however, by no means invariable: and generally speaking, choleate of soda (or bile) may be expected to be absent when the fæces have remained for some time in the large intestine, and there has been full opportunity for resorption.

It follows that the carbonate of lime is a product of the double decomposition that occurs between the sulphate of lime and the carbonate of soda resulting from the incinerated choleate of soda, or bile.

The formation of the membrane during evaporation indicates the presence of a certain amount of albumen.

In 100 parts of the ash yielded by the excrement of another individual, there were contained:

Chloride of sodium and alkaline sulphates	-	-	1.367	} soluble in water.
Bibasic phosphate of soda	-	-	2.633	
Phosphates of lime and magnesia	-	-	80.372	
Phosphate of iron	-	-	2.090	
Sulphate of lime	-	-	4.530	insoluble in water.
Silica	-	-	7.940	
<hr/>				
98.932				

From the absence of carbonate of lime in this instance, it may be concluded that no choleate of soda or bile was present. The excrement was very firm and solid.

I am indebted to the kindness of Dr. Percy for the following analyses of the faeces.

1. The individual, who was about thirty years of age, had taken the ordinary diet of this country, and appeared to be in the enjoyment of perfect health.

In 100 parts of dried residue there were contained:

Substances soluble in ether (brownish yellow fat)	-	-	-	11.95
" in alcohol of '830	-	-	-	10.74
" in water (brown resinoid matter)	-	-	-	11.61
Organic matter insoluble in the above menstrua	-	-	-	49.33
Salts soluble in water	-	-	-	4.76
Salts insoluble in water	-	-	-	11.61

An ultimate analysis of the faeces in this case was also instituted. "I may here premise," says Dr. Percy, "that I have invariably used chromate of lead as the oxidizing body, and have occasionally sheathed the combustion tube with thin sheet copper, in order to enable me to attain a high degree of heat towards the close of the combustion, a precaution essentially necessary in the analysis of these matters, as the last trace of carbon cannot, without this precaution, be completely burned. In corroboration of this statement I may mention that the perfect incineration of faeces at a red heat requires a considerable time. The matter was prepared for analysis by first drying over the water-bath, and then either in an oven at the temperature of 212° or some degrees above, or in the salt-water bath and by a current of air desiccated by chloride of calcium. I was extremely particular in respect to the drying, and, generally, in a second analysis, employed matter which had been subjected to the drying process for a much longer time than in the first, so that the correctness of the proportion of hydrogen should be satisfactorily tested.

1st Analysis: 7.41 grm. gave—of water 4.43 or of hydrogen 6.64g., of CO₂ 12.55 or of C 46.18g.

2d Analysis: 7.24 grm. gave—of water 4.44 or of hydrogen 6.81g., of CO₂ 12.28 or of C 46.23g.

Incineration: 50.13 grm. gave—of ash 8.21, or 16.37g.

Nitrogen—not yet determined.

Taking the mean, we have:

C	46.20	}
H	6.72	
N & O	30.71	
Ash	16.37	

"These results are very nearly the same as those obtained by Dr. Playfair,¹ at Giessen. His analysis gives C 45.24, H 6.88, N & O 34.73, ash 13.15. These facts are worthy of attention, as they seem to show that, under ordinary circumstances of health, the composition of the faeces is more uniform than we might *a priori* have anticipated. The first analysis, it will be borne in mind, was of the faeces of a man in this country; the second, of a soldier at Giessen.

¹ Liebig's Animal Chemistry, 2d edition, p. 285.

"2. A man undergoing the curious and rigorous discipline of training for prize-fighting. This individual, it will not be doubted, was in the possession of the most perfect health. He had been in training for about a week. Age, 22; height, 5ft. 6in.; weight, 8½ stones. I request particular attention to the diet. He breakfasted at 9 a. m., and took one pound of mutton weighed before cooking. He dined at 1 p. m., took the same quantity of mutton, and about two ounces of bread. He had the same quantity of mutton for supper at 8 p. m. At each meal he drank half a pint of ale, and no other liquid during the day; nor, it must be remembered, had he any other vegetable matter besides the small quantity of bread mentioned. He walked seventeen miles daily.

1st Analysis: 5·35 grm. gave—of HO 3·43 or H 7·12% of CO₂ 9·73 or C 49·60%.

2d Analysis: 5·74 grm. gave—of HO 3·62 or H 7·01% of CO₂ 10·52 or C 49·98%.

The difference between these two analyses, in respect to the carbon, is greater than should be allowed, but I had not time to make a third analysis.

Incineration: 31·42 grm. gave—of ash 4·56, or 14·51%.

Mean—C	:	:	49·79	} 100·00
H	:	:	7·06	
N & O	:	:	28·64	

Ash : : : 14·51

"I should observe that, in drying this specimen, towards the end of the process a small quantity of liquid condensed on the surface of the tube communicating with the vessel of water, which was clear and colourless, had a peculiar and extremely offensive odour, and which powerfully reddened litmus. I had not sufficient leisure to examine it more minutely at the time."¹]

The fæces during disease.

In certain pathological conditions, the fæces frequently undergo very important modifications. These changes cannot be due to any peculiarities in the ingesta; they must originate in an alienated mixture or separation of the secretions of the chylopoietic viscera. This irregularity may lead to imperfect chymification, in which case matters will be carried off with the fæces, which, if they had been properly digested, would have entered the vascular system; or, in consequence of the changed process of secretion, substances which are normal secretions may be separated in too large a quantity, as, for instance, water; or substances which ought to be present, are entirely absent, as, for instance, bile; or, lastly, substances which are altogether foreign to the normal secretions, are mixed with the fæces, as albumen, blood, &c.

¹ I strongly suspected the matter to be butyric acid, and my suspicion has since been much strengthened by my examination of a specimen of pure butyric acid which I had an opportunity of seeing in London, at the Pharmaceutical Society. Besides, Dr. Erwin Waidele, whom I had the pleasure of meeting at Professor Graham's, informed me that Dr. Ragsky of Vienna has discovered this acid in the fæces.

In the case of diabetes alluded to in p. 519, I carefully examined the faeces. They contained no sugar, and were chiefly remarkable for their large amount of solid fat. Two or three pulaceous stools, averaging collectively 18.5 ounces, were passed daily. They gave off a very disagreeable odour, and were of a grayish clay colour.

Alcohol digested with this faecal matter became coloured brown, and extracted a large quantity of fat, extractive matter, and a little bilin. On treating the portion insoluble in alcohol with water, a small amount of water-extract, almost devoid of taste, was taken up. The insoluble residue yielded, on incineration, an odour of burned horn or glue, and contained a large amount of nitrogen.¹ A quantitative analysis showed that the 18.5 ounces of faecal matter contained:

	Analysis 151.		
	Whole quantity. In 100 parts.		
	oz.	grains.	
Water	12	312	
Solid constituents	5	408	
Fat	2	0	34.0
Bilin and extractive matter soluble in alcohol	0	56	2.0
Water-extract	0	56	2.0
Alkaline salts	0	182	6.5
Carbonate of lime	0	70	364
Earthy phosphates and peroxide of iron	0	112	4.0
Insoluble nitrogenous matters	2	359	47.0

I have attempted in accordance with the plan laid down in the appendix to Liebig's 'Animal Chemistry,' to compare the amount of carbon, nitrogen, and hydrogen in the food and in the excretions.

The ingesta consisted of:

8 oz. of dry gluten bread.
11.5 " dry meat.
2 " dry egg.
2 " cod-liver oil.

23.5 ounces.

There were discharged :

By the urine.	From the bowels.
8.8 oz. of sugar.	2 oz. of fat.
1.3 oz. of urea.	2.5 oz. of nitrogenous insoluble fecal matter
15 grains of uric acid.	and protein-compounds.
100 grains of extractive matter and bilin.	

15 ounces.

There is then an excess of 8.5 oz. of food.

In the food there are contained;	In the excretions there are contained:
12 oz. of carbon.	6.6 oz. of carbon.
1 oz. 6 drms. of hydrogen.	1 oz. of hydrogen.
2.5 oz. of nitrogen.	410 grains of nitrogen.
700 grains of fixed salts.	710 grains of fixed salts.

Hence there are carried off, by respiration and transpiration, 5.5 ounces of carbon, 0.75 of hydrogen, and 1.62 of nitrogen.

This quantity of carbon and hydrogen is much less than is generally supposed to be carried off by the lungs; and with respect to the

¹ [This is entirely opposed to the experience of Lehmann, who states that the faeces of diabetic patients frequently yield a mere trace of nitrogen. Lehrbuch der physiologischen Chemie, 1842, p. 312.]

nitrogen, although we may assume that some is carried off by the skin, the disproportion is still very great. An accurate examination of the expired air might throw much light on this obscure and remarkable morbid process.

[I am indebted to Dr. Percy for the following analyses of diabetic faeces:

1. "Faeces of a boy aged 7 years. It was found impossible in this case to enforce a rigid system of animal diet, so that we may regard these faeces as the faeces of diabetes unchecked or modified by treatment. They were hard, and not of the natural consistence of health.

1st Analysis: 5·44 grs. gave—of HO 3·35 or H 6·83% of CO₂ 8·76 or C 43·94%.

2d Analysis: 4·72 grs. gave—of HO 3·01 or H 7·09% of CO₂ 7·58 or C 43·79%.

Incineration: 30·76 grs. gave—of ash 6·18, or 20·09%.

Mean—C	.	.	.	43·86	100·00
H	.	.	.	6·96	
N & O	.	.	.	29·09	
Ash	.	.	.	20·09	

The proportion of saline matter is here much greater than usual, and, doubtless, depended upon constipation.

The fat taken up by ether amounted to 16·16% of the dried faeces.

2. "The faeces of a man (Flint) aged 48 years, who was labouring under diabetes of long standing. He was restricted principally to animal food, a small quantity of bread only being allowed. Consistence moderate. This analysis was executed under my own supervision by my former pupil, Mr. Stallard.

1st Analysis: 8·22 grs. gave—of HO 5·61 or H 7·58% of CO₂ 16·43 or C 54·51%.

2d Analysis: 8·57 grs. gave—of HO 5·84 or H 7·57% of CO₂ 17·03 or C 54·20%.

The nitrogen was determined by Wills's method.

Nitrogen: 6·29 grs. gave—of metallic platinum 5·33 grs., which corresponds to 12·01% of nitrogen.

Incineration: 61·01 grs. gave of ash 5·71, or 9·36%.

Mean—C	.	.	.	54·35	100·00
H	.	.	.	7·57	
O	.	.	.	16·71	
N	.	.	.	12·01	
Ash	.	.	.	9·36	

Proximate Analysis:

Substances soluble in ether	-	-	-	-	23·00	100·00
" alcohol	-	-	-	-	11·13	
" water	-	-	-	-	12·02	
Organic matter, insoluble in these menstrua	-	-	-	-	45·49	
Ash	-	-	-	-	9·36	

3. "Faeces of the same individual some weeks afterwards, while taking about three ounces of fat bacon daily, in addition to his usual animal diet. It was evident after drying, that these faeces abounded in fat from their appearance on the application of heat. It was impossible to reduce them *per se* to fine powder.

1st Analysis: 5·06 grs. gave—of HO 4·22 or H 9·22% of CO₂ 11·20 or C 60·36%.

2d Analysis: 6·28 grs. gave—of HO 5·25 or H 9·28% of CO₂ 13·89 or C 60·32%.

Incineration: 55·93 grs. gave—of ash 7·40, or 13·23%.

Mean—C	60·34	} 100·00
H	9·25	
N & O	17·18	
Ash	13·23	

Ether took up a quantity of fat amounting to 51·55% of the dried faeces.

4. "Faeces of the same individual a few weeks afterwards, while restricted to an animal diet of the lean of meat: as far as it was practicable all fat was removed.

1st Analysis: 7·06 grs. gave—of HO 5·05 or H 7·95%, CO₂ 13·72 or C 53·00%.

2d Analysis: 6·62 grs. gave—of HO 4·77 or H 8·00%, CO₂ 12·93 or C 53·27%.

Incineration: 16·81 grs. gave—of ash 2·96, or 17·60%.

Mean—C	53·09	} 100·00
H	7·97	
N & O	21·34	
Ash	17·60	

5. "Faeces of a man (Roberts¹) between 30 and 40 years, labouring under diabetes of some standing. Diet, exclusively animal, with the exception of a small quantity of bread.

1st Analysis: 4·53 grs. gave—HO 3·07 or H 7·53%, CO₂ 7·64 or C 45·99%.

2d Analysis: 5·33 grs. gave—HO 3·67 or H 7·65%, CO₂ 8·92 or C 45·64%.

Incineration: 50·84 grs. gave—of ash 10·77, or 21·18%.

Mean—C	45·81	} 100·00
H	7·59	
N & O	25·42	
Ash	21·18	

6. "Faeces of the same individual, some weeks afterwards, while on a mixed diet. At this time also he was much emaciated and exhausted, in consequence probably of having been obliged to work, and to subsist on a mixed diet.

1st Analysis: 5·13 grs. gave—of HO 3·36 or H 7·28%, CO₂ 8·63 or C 45·88%.

2d Analysis: 4·86 grs. gave—of HO 3·18 or H 7·27%, CO₂ 8·21 or C 46·07%.

Incineration: 32·31 grs. gave—of ash 7·14, or 22·10%.

Mean—C	45·97	} 100·00]
H	7·27	
N & O	24·66	
Ash	22·10	

In dysentery the stools are thin, contain flocculent mucus, and are either almost colourless or milky, (dysenter. catarrh.) or they are coloured red by blood (dysenter. inflammat.) According to Schölein they possess a peculiar smell quite characteristic of the disease.

On examining the white or slightly coloured mucous fluid under the microscope, we observe numerous mucus-corpuscles floating about in it: the red, sanguineous discharges also contain an extraordinary number of mucus-corpuscles, numerous blood-corpuscles, but no (or very few) epithelium-scales.

We sometimes find pseudo-membranous portions of exuded plastic lymph mixed with the stools, especially in the most inflammatory forms of the disease.

¹ Roberts' case has been published in the Medical Gazette. He has since died, and the sequel will shortly appear, together with the cases of the child affected with diabetes, and of the other patient Flint.

In typhous diarrhoea the motions are frequently very bulky, of a chocolate colour, frothy, mixed with black dissolved blood, and not giving off the peculiar odour of dysenteric evacuations, but rather a cadaverous smell. In bilious diarrhoea the bile-pigment is mixed with the fluid motions, which are less copious than in the former case.

In enteritis mucosa the stools, especially those which are discharged during the night, are thin, and, in addition to the mucus and faecal matters coloured yellow by bile-pigment, contain a peculiar flocculent mass, like exuded lymph, which, on more accurate examination, seems to consist of purulent and fatty matter. Blood is likewise sometimes found in these stools.

In abdominal typhus the stools are very characteristic; in the first stage they do not differ very much from the normal state; they are sometimes very firm, sometimes very thin and watery. In a more advanced stage of the disease, they separate when shaken in a glass vessel into two strata; the lower one forms a slightly yellow flocculent mass, while the upper one is composed of a cloudy, whey-like fluid. On examining the flocculent material under the microscope, I found that it was composed, for the most part, of small lumps of mucus or pus, of an amorphous yellow matter—probably coagulated albumen with bile-pigment, of a comparatively small quantity of epithelium, and sometimes of extremely numerous and beautifully formed crystals of ammoniacal-magnesian phosphate, such as are depicted in fig. 27: sometimes we find, as also in phthisis intestinalis, small white masses about the size of a millet, or half as large as a hemp-seed; they are easily triturated, and then have a greasy appearance; when examined under the microscope they appear to be composed of cells similar to primary cells, or what are called the globules of inflammation. The contents of these spherical cells, which are enclosed in a very delicate membrane, are coarsely granulated and escape on the least pressure.

In some of the larger parent cells, I found smaller cells with nuclei. I dried a portion of the flocculent precipitate; on incinerating the residue I obtained 32% of salts, of which nearly one half, namely, 14·6 were earthy phosphates.

The whey-like fluid which is above the sediment, is usually tolerably rich in albumen. It coagulates, or at any rate becomes turbid on the application of heat or nitric acid. In most cases it has a strong alkaline reaction, and contains a large amount of carbonate of ammonia, which frequently interferes with the action of heat on the albumen.

In some cases I observed that a beautiful rose-red tint was produced by the addition of nitric acid, of which I shall speak more fully in my observations on the stools in cholera. Typhus stools are sometimes tinged with blood.

In melæna blackish pitchy blood is mixed with the faeces, which sometimes consist entirely of that substance. I have previously described the peculiarities of the blood. (See p. 259.)

In catarrhus intestinor. the intestinal mucous membrane acts very much the same as the mucous membrane of the respiratory organs in pulmonary catarrh. The secretion is at first checked, then very much increased, and, finally, after secreting thick and tough mucus, returns to its normal condition.

In simple diarrhoea a thin muco-aqueous yellow, or yellowish-brown discharge follows the evacuation of the true faeces.

In bilious diarrhoea the stools are also liquid, but they are generally of a greenish colour, and possess so strong an acid reaction as to produce excoriation of the anus.

In dysenteric diarrhoea a large quantity of gray or greenish mucus tinged with blood, is discharged. In diarrhoea lactantium, masses are discharged which are not unlike chopped eggs: they have a strong acid odour, and exert a corroding effect on the vicinity of the anus.

In Asiatic cholera it is well known that an extraordinary quantity of watery fluid is discharged by the intestines.

Dulk found that the evacuations in cholera had an alkaline reaction, that they contained albumen, and that they were entirely devoid of the ordinary odour of faeces.

Hermann,¹ on the contrary, found that they had an acid reaction, and resembled the vomited matter, in which he detected free acetic acid. The ordinary reaction of the stools in cholera is, however, alkaline, and this was observed in a very severe case of sporadic cholera that fell under my own observation.

According to Vogel's observations, the stools in this disease resemble turbid whey: the fluid has a powerful alkaline reaction, and effervesces on the addition of an acid. On distilling a portion of the fluid he obtained in the receiver a liquid with an alkaline reaction, and having a fishy odour. On the addition of nitric acid this liquid assumed a beautiful red tint, which it retained during evaporation. The fluid, when concentrated, had an intense red colour, but was devoid of odour, which only became again apparent on neutralizing the free acid by an alkali.

The portion that remains in the retort after the distillation of the fluid contains traces of albumen, some intestinal mucus, the ordinary salts of the animal fluids, and a large amount of carbonate of soda.

Wittstock's researches respecting the faecal discharges in cholera, coincide in most points with those of Vogel: he observed the beautiful rose-red tint that was produced by the addition of nitric acid, and he ascribed it to the presence of a urate; it is however known, that the formation of purpurea of ammonia or murexid from uric acid, requires a greater degree of concentration of the reacting substances, and a heightened temperature.

The faeces of a woman who had a very severe attack of sporadic cholera, (whose blood and urine I likewise analyzed,) formed a turbid and colourless fluid, which had a strong alkaline reaction, and ef-

¹ Poggend. Annalen, vol. 22, p. 161.

fervesced on the addition of acids, giving off carbonic acid and sulphuretted hydrogen, which, in all probability, arose from carbonate of ammonia and sulphuret of ammonium (hydrosulphate of ammonia.)

When allowed to stand for some time it formed a sediment, which consisted, for the most part, of mucus-corpuscles, with some crystals of ammoniac-magnesian phosphate. No epithelium cells were observed. On treating the fluid with nitric acid, effervescence took place, and flocculi of coagulated albumen separated themselves; moreover, the fluid in a short time became of a rose-red colour,—a phenomenon that was induced more rapidly by gentle warmth: when strongly heated for some time the colour entirely disappeared.¹

The quantitative analysis of the faecal discharge in this case gave the following results, calculated for 1000 parts:—

	Analysis 152.
Water	980-00
Solid constituents	20-00
Fat	0-08
Extractive matter	4-80
Albumen and mucus	0-52
Chloride of sodium, lactate and acetate of } soda, and alkaline phosphates {	13-40
Phosphates of lime and magnesia	0-60

This analysis bears out the result of the investigation of the blood, given in page 266.

Landerer² has analyzed the faecal evacuations of a child suffering from diarrhoea infantilis. It was a yellow fluid, with an acid and bitter taste, and its specific gravity was 1038.2. Landerer found in it: carbonate of lime 1.50; phosphate of lime 2.00; chloride of calcium 1.50; chloride of magnesium 2.45; chloride of sodium 2.43; sulphate of lime 1.50; sulphate of magnesia 0.80; bilin, butyric acid, and extractive matter 3.00; spirit extract 1.00; free lactic and hydrochloric acids 1.00.

In enterorrhysis, the faecal evacuations likewise separate into two strata: the lower is flocculent, and when examined under the microscope is seen to consist of mucus- or pus-corpuscles mingled with remnants of food, or with an amorphous mass tinged with pigment. Sometimes we find, in the deposit from these evacuations, small white or yellow masses, which consist of cells, and can be easily crushed (such as I have already described in speaking of the evacuations in typhus,) and mixed with them there are numerous fat-vesicles. A little blood is not unfrequently observed in these stools; they then have a chocolate or dark blood-red tint. The supernatant fluid is turbid, and of a yellow, brown, or bloody tint; it always contains a considerable amount of albumen.

In icterus the faeces are generally devoid of all the constituents of

¹ [In an examination of the faeces in cholera, instituted by Heller, (*Archiv i. p. 18.*) a similar reaction was observed. The exact nature of the change that the bile-pigment undergoes in such cases is not clearly understood.]

² *Journal f. prakt. Chemie*, 1841, vol. 17, p. 62.

the bile: they are consequently of a white or grayish white colour; they are usually very firm, and deficient in moisture.

[I am indebted to Dr. Percy for the following ultimate analysis of the faeces in jaundice.

A young woman affected with jaundice in a mild form, depending probably on functional derangement of the liver. The faeces were brown, and not clay-coloured, as in severe jaundice.

1st Analysis—5.59 grs. gave of HO 3.66 or H 7.27%, CO₂ 9.69 or C 51.42%.

2d Analysis—5.12 grs. gave of HO 3.37 or H 7.31 g., CO₂ 9.69 or C 51.61 g.

Incineration—28.18 gms. gave of ash 3.41 gms., or 12.10%

Mean-C	-	-	-	51-51	} 100-001
H	-	-	-	7-29	
N & O	-	-	-	29-10	
Ash	-	-	-	12-10	

A physician of this city sent me a white, roundish, easily compressible mass, resembling caseous matter, which had been evacuated after an ordinary motion, by a lady who was suffering from bilious sensations. When observed under the microscope, this substance, which emitted a rather disagreeable odour, was found to be composed of an extraordinary quantity of fat arranged in a structureless, albuminoid mass; no tissues or cells were detected. The mass, when heated, gave off a very strong odour of butyric and acetic acids: it melted and burned with a clear flame. Alcohol extracted a very large amount of fat, consisting of margarin, olein, and butyrin, with their acids, which partially separated on cooling. In the separated flocculi I detected, with the aid of the microscope, crystals of margaric acid, but none of cholesterin. After the evaporation of the

¹ The following table shows, at a glance, the results of the preceding ultimate analyses:

TABLE OF COMPOSITION, EXCLUSIVE OF ASH.

alcohol, water dissolved some butyric and acetic acids from the residue.

The portion insoluble in alcohol was digested for a considerable time in dilute acetic acid, and was precipitated from this solution by ferrocyanide of potassium.

Water did not extract any matter that was precipitable by the last named reagent.

On incineration a considerable amount of ash was left which had an acid reaction, did not effervesce with acids, and consisted almost entirely of earthy phosphates; it contained no sulphates.

Calomel stools.

In certain morbid conditions of the system calomel is frequently given in considerable quantity; its administration is succeeded by numerous, very green, bilious stools. I endeavoured to determine by an experiment whether the bile and its pigment is the actual cause of the colour of these evacuations. The fifth stool that was passed after the administration of a large dose of calomel, was made the subject of the analysis. It was fluid, perfectly green, had no faecal odour, exhibited a mild acid reaction, and showed, under the microscope, a great number of mucus-corpuscles and epithelium-cells. On evaporation it gave off an odour resembling that of saliva or extractive matter under similar circumstances. Ether extracted from the solid residue a considerable amount of fat which had an acid reaction, contained cholesterin, and was covered with biliverdin. All other substances which were separated from it by water and alcohol were more or less coloured by bile-pigment.

Bilin with bilifellinic acid and biliverdin were found in large quantity; by digestion with sulphuric acid the bilin became entirely converted into biliary resin. From a quantitative analysis it appeared that 100 parts of the solid residue of this evacuation were composed of:

	Analysis 153.
Green fat containing cholesterin	10·0
Salivary matter soluble only in water, and slightly precipitated by tannic acid and acetate of lead	24·3
Bilin with bilifellinic acid and biliverdin, collectively soluble in anhydrous alcohol	21·4
Extractive matter soluble in spirit	11·0
Albumen, mucus, and epithelium-scales	17·1
Salts	12·9
	<hr/>
	100·0

Various attempts that I made (by Smithson's method) to detect mercury in calomel-stools proved unsuccessful.

[Dr. Golding Bird has published an analysis of the green evacuations so frequently observed in children. The specimen examined by him "was passed by a hydrocephalic infant whilst under the in-

fluence of mercury, and presented the following characters. It was a dirty-green turbid fluid which, by repose in a glass vessel, separated into three very distinct portions:—1, a supernatant fluid, of oil-like consistence, presenting a brilliant emerald-green colour; 2, a dense stratum of mucus, coagulated albumen, and epithelial debris, mixed with red particles of blood; 3, a deposit, occupying the lower part of the vessel, of large crystals of ammoniac-magnesian phosphate, in fine prisms of an apple-green colour.

The supernatant emerald-green fluid was decanted for examination.

A. It was faintly alkaline, possessed a broth-like odour, and a density of 1020.

B. The addition of a few drops of nitric acid did not alter the colour, even after ebullition. A larger quantity of the acid being added whilst the mixture was boiling, converted the emerald-green colour into a pinkish-yellow; the green colour was not restored by the subsequent addition of an alkali.

C. Acetic acid scarcely affected the green fluid, producing no apparent coagulation of mucus.

D. A solution of acetate of lead threw down a copious grayish-green, tenacious precipitate, leaving the supernatant fluid colourless.

E. Bichloride of mercury produced a light-green precipitate, leaving the supernatant fluid pale, but not decolorizing it.

It was analyzed in the following manner:

1. 1000 grains of the green fluid left, by careful evaporation, a deep olive-green, highly deliquescent extract, weighing 100 grains.

2. This extract, on being immersed in alcohol of .837 formed a mass like birdlime, which could not be mixed with the spirit. Even after long boiling, it appeared hardly to diminish in bulk. The clear tincture being decanted, left, however, an extract weighing 30 grains. This residue possessed the yellowish-green colour of faded leaves, an odour of fresh broth and a sweet sub-astringent taste, with a very slight admixture of bitterness.

3. The alcoholic extract being carefully incinerated, left 5.5 grains of ash, consisting chiefly of chloride of sodium mixed with mere traces of tribasic phosphate of soda ($3\text{NaO}_3\text{PO}_4$) It was alkaline, but did not effervesce with acids.

4. The portion left undissolved by boiling alcohol yielded to water 13 grains of nearly tasteless matter which, by incineration, left a powerfully alkaline ash weighing 1.75 grains, not effervesing with acids, and consisting nearly exclusively of alkaline tribasic phosphate of soda.

5. The residue insoluble both in water and alcohol weighed 57 grains, and consisted almost entirely of coagulated albumen, dry mucus, and modified blood. It left by incineration one grain only of ash, consisting almost wholly of black-red peroxide of iron.

The following is a view of the results of the examination:

Alcoholic extract	{	Organic	:	:	:	24.50
		Inorganic	:	:	:	5.50
Aqueous extract	{	Organic	:	:	:	11.25
		Inorganic	:	:	:	1.75
Insoluble matter	{	Organic	:	:	:	56.00
		Inorganic	:	:	:	1.00
Water and volatile matter						900.00
						<hr/>
						1000.00

The organic portion of the alcoholic extract consisted chiefly of fatty matter, cholesterin, and a green substance probably identical with biliverdin; with these were traces of bile barely sufficient to communicate a bitter taste to the extract, and in too small a quantity to leave any carbonate of soda in the residue of incineration. The aqueous extract consisted chiefly of ptyalin and the extractive matters comprehended under the general term of "extrait de viande," by Berzelius. The composition of the fluid part of the green evacuation may therefore be thus expressed:

Water						900.00
Biliverdin, alcoholic extract, fat, cholesterin, with traces of bile						24.50
Ptyalin, aqueous extract coloured by biliverdin						11.25
Mucus, coagulated albumen, and haematin						56.00
Chloride of sodium, with traces of tribasic phosphate of soda						5.50
Tribasic phosphate of soda						1.75
Peroxide of iron						1.00
						<hr/>
						1000.00

Professor Kersten of Freiberg has recently published a paper on the cause of the green evacuations observed after a course of the Marienbad waters for fifteen or twenty days.

The occurrence of these evacuations is regarded as critical and highly favourable. Kersten denies that the tint is in any degree dependent on the presence of bile, and ascribes it to the formation of green sulphuret of iron.

In the paper referred to, he first shows that on the addition of very dilute hydrochloric acid to an evacuation of this nature diluted with thrice its weight of water, there is a development of sulphuretted hydrogen, indicating the presence of a metallic sulphuret; moreover, on the addition of ferrocyanide of potassium to the filtered acid solution a bright blue precipitate is observed, which becomes darker after exposure to the air, indicating the existence of protoxide of iron. This experiment shows that the green pigment is destroyed or decomposed by dilute hydrochloric acid, and further, that it is a compound of sulphur and iron. He accounts for the presence of the sulphuret of iron in this way. The sulphate of soda present in the water is reduced in the stomach to a sulphuret of sodium by the de-oxidizing power of the organic matters with which it is in contact, aided by a temperature favourable to such a change. The bicarbonate of iron in the water is decomposed at the temperature of the stomach, and the iron precipitated either as a protoxide or as a hydrated peroxide, and immediately redissolved by the free acid of the

gastric juice. This reacts on the sulphuret of sodium, and sulphuret of iron is the result.

Since the publication of Kersten's paper, a very similar view has been propounded by Dr. Bley, namely, that the green evacuations observed after the use of calomel are dependent not on the presence of bile, but of sulphuret of mercury. Unfortunately for this theory the mercury cannot be detected by analysis, and Pettinkosfer's test reveals the presence of bile.

Dr. Frankl has published a paper containing various arguments in opposition to Kersten's views, and criticising his conclusions.

Berzelius, on the other hand, writes thus: "It never entered my mind to suspect that this coloration arose from sulphuret of iron, but I always believed that it might be attributed to the black oxide of iron. It is, however, quite natural that as sulphuretted hydrogen is usually produced during the progress of digestion, the oxide of iron present in the intestinal canal should be reduced to a sulphuret, no matter whether sulphates have been given or not."

Berzelius renders Kersten's view more general, observing "that every chalybeate water, whether it contain sulphates or not, produces a similar appearance in the evacuations." On this Kersten remarks: that "the coloration may be most intense when sulphates are present, because by their decomposition during digestion an excess of sulphuretted hydrogen will be generated."

Vomitus. (Matters discharged by vomiting.)

It is well known that the fluid which is found in the stomach, and which is a mixture of gastric juice, saliva, and remnants of food, becomes much changed in its properties in certain morbid conditions of the system. I need scarcely refer to the excess of free acid, and to the presence of bile in certain conditions of the stomach. On the occurrence of the latter of these states we usually observe a separation, or peeling off, of the upper stratum of epithelium-scales from the tract of mucous membrane between the pharynx and the stomach, and this condition is recognised by the gastric furred tongue.¹

This fur or coating has been analyzed by Denis: he found that one half consisted of phosphate and carbonate of lime, the other half of mucus.

In gastrodynbia, even when there is no food in the stomach, the gastric juice is secreted in such an acid condition as to set the teeth on edge. This is chiefly caused by free hydrochloric acid, but concentrated lactic and acetic acids will produce the same effect.

In gastritis, colonitis, enteritis, and peritonitis, a grass-green liquid is often brought up; it is frequently mixed with green or white flocculi, and on other occasions is quite clear; it almost always has an acid reaction, and usually contains a considerable amount of fat.

¹ On examining the thick coating of the tongue in cases of abdominal typhus, I have found that it is composed of matted epithelium scales over which minute sporules are scattered. The sores from the teeth exhibited similar characters.

I analyzed a fluid of this sort that was vomited during peritonitis: it had a greenish, viscid appearance, and contained whitish flocculi that presented an amorphous character under the microscope. It did not affect blue or red litmus paper; on the addition of nitric acid there was a separation of white flocculi, and the fluid became first of a pale blue and subsequently of a reddish tint. On the application of heat some globules of oil separated themselves, and a small quantity of albumen became coagulated; it contained 2·9% of solid constituents, from which ether took up a yellow liquid fat that was imperfectly soluble in cold, but dissolved easily in hot alcohol; it contained a little cholesterin, and gave off a smell like that of a fatty acid.

Alcohol took up extractive matter and bilifellinic acid, which latter could be separated by means of sulphuric acid; dilute alcohol took up spirit-extract with a little bilifellinic acid. A considerable amount of the portion that was insoluble in spirit dissolved in water, and was again precipitated by alcohol, tannic acid, and acetate of lead. The precipitate thrown down by alcohol was soluble in an excess of water, which was rendered turbid by the addition of acetic acid, and yielded a copious precipitate on the subsequent addition of ferrocyanide of potassium.

As the ash, after incineration, consisted of carbonate of soda, I regarded the substance insoluble in alcohol as an albuminate of soda.

The quantitative analysis of this "vomitus æruginosus seu herbaeus" yielded the following proportions in 1000 parts:

	Analysis 154.
Water	971·0
Solid residue	29·0
Fat	4·3
Bilifellinic acid, alcohol-extract, and bile-pigment	1·5
Spirit-extract with a little bilifellinic acid	11·4
Albuminate of soda	5·4
Mucus and albumen	5·8

[Heller¹ analyzed a brilliant green fluid vomited by a young woman aged 20 years, suffering from peritonitis.

In quantity it amounted to about three ounces; it was slightly turbid, and threw down a considerable sediment which was viscid, more of a yellowish tint than the supernatant fluid, and consisted of epithelium-cells and mucus-corpuscles.

The fluid had an acid reaction, but contained neither free hydrochloric nor acetic acid. Its specific gravity was 1006. On the addition of nitric acid it first became blue, and afterwards of a beautiful carmine red. It contained no albumen.

In 1000 parts there were contained:

Water	990·50
Solid constituents	9·50
Fat	0·24
Water-extract	1·30
Biliverdin with a little biliphein and a trace of alcohol-extract	5·38
Fixed salts	3·75

¹ Archiv. vol. 1, p. 226.

The salts consisted for the most part of the chlorides of sodium and calcium, associated with less quantities of phosphate of soda, sulphate of potash, and earthy phosphates. Urea and uric acid were sought for without success.

The green colour seems undoubtedly due to the presence of biliverdin, which is probably formed in the stomach by the action of the acid solution of hydrochlorate of lime on the biliphaein. Hence the occurrence of green vomiting need not be regarded as indicative of any peculiar morbid change.

A brief notice of a green fluid vomited during an attack of sporadic cholera, may be found in vol. 1, p. 18, of Heller's Archiv.]

Vomitus with urinary constituents.

It is stated that in those cases in which the formation and excretion of the urine are impeded, its constituents are discharged with vomited matters.

Nysten¹ and Barruel had an opportunity of analyzing a vomited fluid which contained urea, uric acid, and the ordinary urinary salts.

[Dr. Halliday Douglas has reported a case in which urea was detected in the vomited fluid. London and Edinburgh Monthly Journal of Medical Science, vol. i. p. 410.]

Vomitus in carcinoma.

In carcinoma of the stomach a fluid is vomited which deposits masses of chocolate or coffee-coloured flocks on the bottom of the vessel, while others are observed on the surface of the fluid. On examining a few of them under the microscope, we observe a considerable quantity of large rounded cells with yellow granular contents, and also a very great number of fat-vesicles, some larger and others smaller than the cells. Remnants of food, and especially undigested starch-granules, are likewise frequently observed. The latter may be easily mistaken for fat-vesicles, but moderately strong compression causes their envelopes to break, and on the addition of a solution of iodine they assume a blue colour. By this test all ambiguity is avoided.

[Dr. George Wilson has published a notice of the chemical and microscopical characters of the fluid ejected in pyrosis—the ordinary water-brash. The most remarkable of these is the appearance of a microscopic cryptogamic plant (*sarcina ventriculi*), and of acetic, lactic, and carbonic acids in the liquid. The first case in which these were found, occurred to Mr. Goodsir, and was published by him in the 'Edinburgh Medical and Surgical Journal' for April, 1842. Since that period a case has occurred in the practice of Mr. Benjamin Bell of Edinburgh, who allowed Mr. Goodsir and Dr. Wilson to examine the fluid ejected by his patient, in which the same organism and acids were discovered; and Mr. Busk, of the

¹ Journ. de Chem. Med. 1820, Ser. III. p. 257.

Dreadnought hospital ship, Greenwich, has published the history of three cases where the *sarcina* presented itself, but no analysis was made of the fluids in which it appeared.

On examining the fluid with the microscope, the *sarcina* is found to present the following characters.¹ In every instance the organisms presented themselves in the form of square or slightly oblong transparent plates, of a pale yellow or brown colour, and varying in size from the 800th to the 1000th of an inch. They were made up of cells, the walls of which appeared rigid, and could be perceived passing from one flat surface to another as dissepiments. These dissepiments, as well as the transparent spaces, were, from compression of contiguity, rectilinear, and all the angles right angles; but the bounding cells bulged somewhat irregularly on the edges of the organism, by reason of the freedom from pressure. These circumstances gave the whole organism the appearance of a woolpack, or of a soft bundle bound with cord, crossing it four times at right angles, and at equal distances. From these very striking peculiarities of form, Mr. Good sir has proposed for it the generic name of **SARCINA**.²

On examining the ejected fluid in the case recorded by Mr. Good sir, it was found to possess the following characters. It was thick and viscid; on standing, it deposited a large quantity of ropy matter mixed with portions of undigested food, and, when filtered through paper, had a pale brownish yellow colour, and was quite transparent. It still contained much animal matter in solution, becoming opaque and flocculent when boiled, and giving a very copious precipitate with infusion of galls. It also precipitated nitrate of silver densely, and, when evaporated to dryness and exposed to a full red heat in a platinum crucible, left an ash containing much chloride of sodium. It reddened litmus powerfully, and effervesced sharply with alkaline carbonates. It continued strongly acid after being twice distilled, and did not precipitate nitrate of silver, but retained the sour smell, which could now be recognised as identical with that of vinegar. On neutralizing the twice distilled fluid with lime-water, and evaporating to dryness, a salt was obtained, which, on being decomposed in a tube-retort with sulphuric acid, yielded a volatile odorous acid, readily identified by several tests with the acetic.

It was found by several trials, that, on an average, an ounce of the liquid neutralized 0·4 grain of carbonate of potash; a quart (32 oz.) would therefore neutralize 12.8 grains, which correspond to 9 grains of the hydrated (crystallizable) acetic acid, $C_4H_3O_3+HO$. The liquid remaining in the retort continued to reddens litmus powerfully after all the acetic acid had been distilled from it. This was traced in part to the presence of a small quantity of free hydrochloric acid;

¹ The reader is referred to the 'Edinburgh Medical and Surgical Journal' for April, 1842, for a more minute description of the *sarcina*, and a detailed account of the chemical analysis of the liquid containing it.

² *Sarcina*, a pack or wool-pack.

but it was chiefly owing to the existence in the liquid of a considerable proportion of lactic acid. The most remarkable feature of this case, in a chemical point of view, was the large quantity of acetic acid found; the quantity of liquid ejected at once by the patient often amounted to more than two quarts, which would contain 18 grains of acetic acid. In Mr. Bell's case the chemical characters of the liquid were very similar. An additional point was, however, ascertained, namely, the presence of free carbonic acid in the liquid.]

CHAPTER XI.

THE COMPONENT PARTS OF THE ANIMAL BODY.

The Bones.

THE bones are the least destructible of all the parts of the organism. Under favourable circumstances they remain as unchanged as mere inorganic matter, and the amount of cartilage has been found unaltered in bones three thousand years old.¹

The external surface of bone is surrounded by a membrane richly endowed with nerves and vessels—the periosteum, which, as well as the cartilaginous portion, can be converted, by boiling, into gelatin. The interior of the cylindrical bones is lined in a similar manner; the flat and short thick bones are, however, filled in the interior with delicate lamellæ arranged so as to present a cellular appearance: in the flat bones, this is termed the diplöe. If a bone is suspended in dilute hydrochloric acid at a low temperature, all the earthy matter becomes gradually dissolved and the mere cartilage remains, retaining the precise form of the original bone. It is supple, transparent, and soft, but on drying it becomes of a darker colour, hard, and somewhat contracted. When boiled it becomes rapidly converted into gelatin, leaving the fibrous tissue and the vessels of the bone unacted on. These vessels may be exhibited by leaving the bone in dilute hydrochloric acid till about one half of the earthy matter is dissolved: it must then be washed with cold water, and afterwards kept for twenty-four hours in water, nearly at the boiling point. The cartilage from which the earthy matter has been removed, is thus dissolved, and numberless minute vessels may be seen issuing from the undecomposed portion of bone, presenting a beautiful white

¹ This has been observed in the bones of human and animal mummies discovered in Egyptian sepulchres. Apjohn and Stokes found in the bones of an extinct gigantic elk, 48·67 of ordinary cartilage, combined with 43·45 of the phosphates of lime and magnesia with fluoride of calcium, and 9·14 of carbonate of lime, &c. In the teeth of an Egyptian mummy, Lassaigne found 2½ of organic matter; and in the teeth of a fossil bear, 14 of cartilage and 70 of phosphate of lime. Gimbernat prepared an edible jelly from the bones of the Ohio mammoth.

velvety appearance, which is injured by the least motion. If the bone when immersed in dilute hydrochloric acid is exposed to heat, the chemical action is facilitated, and the bone develops carbonic acid and separates into fibrous lamellæ, divisible in a longitudinal direction, which, if they are sufficiently thin, possess the property of polarizing light in the same manner as mica.

When bone is submitted to thorough incineration, all the organic portion is destroyed, and there remains nothing but the earthy matter mixed with certain salts which have been formed during the process of incineration, such as alkaline sulphates and carbonates, and with free lime formed by the expulsion of the carbonic acid from carbonate of lime.

The carbonate of lime in bone is just the same as the natural carbonate of lime; the phosphate, on the other hand, consists of $8 \text{ Ca O} + 3 \text{ PO}_5$, according to Berzelius;¹ and $3 \text{ Ca O} + \text{ PO}_5$, according to Mitscherlich. In addition to these salts we find small quantities of phosphate of magnesia and fluoride of calcium,² and traces of the peroxides of iron and manganese.

[An elaborate treatise on the Chemistry of Bone has been recently published by Von Bibra. We extract the following analysis:—

	Male Fœtus at the 6—7th month.		
	Femur.	Tibia.	Humerus.
Phosphate of lime with barely recognisable traces of fluoride of calcium	53·46	53·46	53·15
Earthy carbonates	3·06	3·10	3·05
Phosphate of magnesia	2·10	2·00	1·96
Salts ³	1·00	1·07	1·02
Cartilage	40·38	40·37	40·82
Fat	a trace	a trace	a trace
	100·00	100·00	100·00

	Female Fœtus at the 7th month.			
	Ulna.	Radius.	Scapula.	Clavicular.
Phosphate of lime with very little fluoride of calcium	57·63	57·67	57·13	56·95
Carbonate of lime	5·86	5·89	5·99	5·75
Phosphate of magnesia	1·10	0·99	1·12	1·07
Salts	0·60	0·67	0·62	0·73
Cartilage	34·78	34·08	34·32	34·54
Fat	0·63	0·50	0·42	0·96

¹ [Berzelius repeated the analysis of the salt last year, and found that its composition is rightly expressed. (*Oefversigt af Kongl. Vat. Akad. Förhandlingar*, 1844, No. 6; or Liebig's und Wöhler's *Annalen*, Feb. 1845.)]

² [The presence of fluoride of calcium in bone has been denied by Rees (*Phil. Mag.* Jan. 1840). The researches of Daubeny and Middleton (*Memoirs and Proceedings of the Chemical Society of London*, vol. 2, pp. 97 and 134) not only demonstrate its almost constant occurrence both in recent and fossil bones, but point out that ordinary water is the vehicle by which it is conveyed into the system. "With regard to the statements of Rees," observes Von Bibra, "I put them to the proof, and found, as was to be expected, that they were altogether incorrect. I used in these experiments the human femur, humerus, and teeth. On treating large quantities of bone-earth with sulphuric acid, I have obtained corrosions on glass sufficiently deep to be felt with the finger-nail." (*Chemische Untersuchungen über die Knochen und Zähne*, p. 103, *Schweinfurt*, 1844.)]

³ The "salts" in the analyses of Von Bibra are the salts soluble in water.

Child aged 2 months.

	Tibia.	Ulna.
Phosphate of lime with a little fluoride of calcium	57.54	56.35
Carbonate of lime	6.02	6.07
Phosphate of magnesia	1.03	1.00
Salts	0.73	1.65
Cartilage	33.86	34.92
Fat	0.82	1.01

Child aged 9 months.

	Femur.	Humerus.	Tibia.	Radius.	Ulna.	Costa.	Scapula.
Phosphate of lime with a little fluoride of calcium	48.11	50.15	48.55	45.38	48.06	42.32	42.61
Carbonate of lime	6.12	6.13	5.79	5.14	6.20	5.00	5.08
Phosphate of magnesia	0.97	1.00	1.00	0.93	1.01	0.89	0.92
Salts	1.23	1.30	1.24	1.07	1.24	1.09	1.10
Cartilage	41.71	39.53	41.50	45.65	41.70	42.55	48.36
Fat	1.86	1.89	1.92	1.83	1.79	2.15	1.93

A child aged 5 years.

A girl aged 10 years.

	Femur.	Tibia.	Femur.	Humerus.
Phosphate of lime with a little fluoride of calcium	59.96	59.74	54.78	54.84
Carbonate of lime	-	5.91	6.00	10.90
Phosphate of magnesia	-	1.24	1.34	1.34
Salts	-	0.69	0.63	0.63
Cartilage	-	31.28	31.34	31.15
Fat	-	0.92	0.96	1.00

A woman aged 25 years.

	Femur.	Tibia.	Fibula.	Humerus.	Ulna.	Radius.	Metacarpus.
Phosphate of lime with a little fluoride of calcium	57.42	57.18	57.39	58.03	57.52	57.38	57.77
Carbonate of lime	8.92	8.93	8.92	9.04	8.97	8.95	8.92
Phosphate of magnesia	1.70	1.70	1.63	1.59	1.71	1.72	1.58
Salts	0.60	0.61	0.60	0.59	0.67	0.63	0.61
Cartilage	29.54	29.58	29.49	29.66	29.14	29.43	29.23
Fat	-	1.82	2.00	1.97	1.09	1.89	1.89

	Os occipit. cipitis.	Costa.	Sternum.	Scapula.	Vertebrae.	Os innominatum.
Phosphate of lime with a little fluoride of calcium	56.35	57.66	52.91	42.63	54.76	44.28
Carbonate of lime	8.88	8.75	8.66	7.19	8.58	8.00
Phosphate of magnesia	1.69	1.69	1.40	1.11	1.53	1.44
Salts	0.59	0.63	0.60	0.50	0.51	0.53
Cartilage	30.66	29.87	33.06	46.57	32.90	43.44
Fat	-	1.83	1.40	2.37	2.00	2.31

A man 25 or 30 years of age.

	Femur.	Tibia.	Humerus.	Ulna.	Os occipit. cipitis.	Costa.
Phosphate of lime with a little fluoride of calcium	59.63	58.95	59.87	59.30	58.43	55.66
Carbonate of lime	7.33	7.08	7.76	7.35	8.00	6.64
Phosphate of magnesia	1.32	1.30	1.09	1.35	1.40	1.07
Salts	0.69	0.70	0.72	0.73	0.90	0.62
Cartilage	-	29.70	30.42	29.28	29.98	33.97
Fat	-	1.33	1.55	1.28	1.35	2.04

¹ This girl died from phlebitis thirteen days after the operation of amputation of the upper arm for caries of the elbow-joint.

	Femur of a man aged 38 years.	
	Compact substance.	Spongy substance.
Phosphate of lime with fluoride of calcium	58.43	42.82
Carbonate of lime	8.35	19.37
Phosphate of magnesia	1.03	1.00
Salts	0.92	0.99
Cartilage	31.47	35.63
Femur of a woman ¹ aged 62 years.	Femur of a woman aged 78 years.	
Phosphate of lime with a little fluoride of calcium	63.17	57.36
Carbonate of lime	4.46	7.48
Phosphate of magnesia	1.29	1.10
Salts	0.90	0.97
Cartilage	28.03	32.16
Fat	2.15	0.93

These are the most recent, and probably the most accurate of any of the analyses of human bone yet published. We may omit, from absolute superfluity of matter, the researches of Schreyer, Rees, Thilenius, Sebastian, Davy, Frerichs, and Stark, which refer merely to the estimation of the organic and inorganic matters, and shall take a brief survey of the more perfect analyses of bone.

Berzelius found in human bone:

Phosphate of lime	-	-	-	51.04
Fluoride of calcium	-	-	-	2.00
Carbonate of lime	-	-	-	11.30
Phosphate of magnesia	-	-	-	1.16
Soda, with a little chloride of sodium	-	-	-	1.20
Cartilage	-	-	-	32.17
Vessels	-	-	-	1.13

Dr. Thompson found² in the human femur:

	1.	2.
Phosphate of lime	43.67	51.12
Carbonate of lime	14.00	9.77
Magnesia	0.49	0.63
Soda	2.00	0.59
Potash	0.06	a trace
Cartilage	39.12	35.93

The four following analyses were made by Valentin:—1 represents the cortical portion of the tibia of a man aged 38 years; and 2, the medullary portion of the same bone; 3 represents the external condyle of the left femur of a girl; and 4, the head of the left tibia of the same individual.

	1.	2.	3.	4.
Basic phosphate of lime	52.930	49.019	37.012	41.774
Carbonate of lime	7.666	7.760	5.038	7.109
Phosphate of magnesia	0.254	1.542	0.874	0.874
Chloride of sodium	0.911	0.441	0.645	
Carbonate of soda	0.204	0.076	1.331	1.677
Cartilage, vessels, &c.	38.020	41.160	55.180	48.560

Marchand found in the compact substance of the femur of a man aged 30 years:

¹ A cretin. The bones had been under ground for four years.

² Animal Chemistry, p. 245.

Basic phosphate of lime	-	-	-	-	-	52.26
Fluoride of calcium	-	-	-	-	-	1.00
Carbonate of lime	-	-	-	-	-	10.21
Phosphate of magnesia	-	-	-	-	-	1.05
Soda	-	-	-	-	-	0.92
Chloride of sodium	-	-	-	-	-	0.25
Cartilage insoluble in hydrochloric acid	-	-	-	-	-	27.23
Cartilage soluble in hydrochloric acid	-	-	-	-	-	5.02
Vessels	-	-	-	-	-	1.01
Peroxides of iron and manganese, and loss	-	-	-	-	-	1.05

The most recent analyses of human bones, with the exception of those by Von Bibra, are those of Lehmann.

Bones of a man aged 40 years who committed suicide.

	Humerus.	Radius.	Ulna.	Femur.	Fibula.	Tibia.
Phosphate of lime and }	56.61	53.25	53.98	58.93	52.99	53.12
fluoride of calcium }						
Carbonate of lime	9.20	9.76	9.51	9.28	9.33	9.35
Phosphate of magnesia	1.08	1.06	1.07	1.09	1.06	1.07
Chloride of sodium	0.37	0.36	0.40	0.40	0.37	0.39
Soda	1.35	1.36	0.98	1.04	1.07	0.99
Organic matter	31.62	33.76	33.23	28.61	34.13	44.10

From the bones of a man aged 44 years he obtained:

	Femur.	Tibia.	Fibula.
Phosphate of lime and fluoride of calcium	52.67	59.93	59.04
Carbonate of lime	10.03	9.88	10.13
Phosphate of magnesia	0.93	0.91	0.89
Soda	1.07	1.09	1.12
Chloride of sodium	0.34	0.31	0.39
Organic matter	34.15	33.94	34.51]

BONES OF THE LOWER ANIMALS.¹

Mammalia.

[EDENTATA. Common armadillo.

	Bony plates from the region of		
	the throat.	the abdomen.	the tail.
Phosphate of lime with a little fluoride of calcium	53.45	50.92	55.43
Carbonate of lime	6.73	6.63	6.99
Phosphate of magnesia	1.30	1.23	1.07
Salts	0.89	0.95	0.92
Cartilage	34.63	36.77	39.81
Fat	3.00	3.50	2.78

GLIRES.

	Squirrel (old)		Mouse. Femur and tibia together.	Rat. Femur.	Hare. Femur.
	Femur.	Humerus.			
Phosphate of lime with a little fluoride of calcium	57.03	55.27	50.31	60.38	59.45
Carbonate of lime	10.45	10.50	9.62	6.72	9.07
Phosphate of magnesia	1.36	1.32	1.10	1.91	0.99
Salts	0.90	0.91	0.63	0.91	0.62
Cartilage	29.46	31.21	36.84	28.98	29.60
Fat	0.80	0.79	1.30	1.10	1.07

¹ The whole of these analyses, with two exceptions, were made by Von Bibra.

RUMINANTIA.

Sheep aged 4 years. He-goat.

Bull aged 4 years.

	Femur.	Os occip.	Femur.	Tibia.	Os occip.
Phosphate of lime with a little fluoride of calcium }	55.94	47.07	54.07	54.03	52.51
Carbonate of lime	12.18	9.09	12.71	11.99	11.14
Phosphate of magnesia	1.00	1.59	1.42	1.44	1.05
Salts	0.50	1.02	0.80	0.70	0.50
Cartilage	29.68	39.58	29.09	29.92	39.80
Fat	0.70	1.65	1.91	1.92	2.00

PACHYDERMATA.

Horse¹ (foetus of about 3 months.) Castrated horse aged 6 years. Mare aged 14 years.

	Humerus and tibia.	Femur.	Humerus.	Femur.
Phosphate of lime with a little fluoride of calcium }	60.51	54.37	52.86	54.63
Carbonate of lime	1.63	12.00	12.07	11.28
Phosphate of magnesia	1.40	1.83	1.75	1.50
Salts	a trace	0.70	0.71	0.40
Cartilage	36.26	27.29	29.70	27.98
Fat	—	3.11	2.91	4.21

	Costa. ²	Metatarsus. ²	Wild-boar. Femur.
Phosphate of lime with a little fluoride of calcium }	42.21	54.29	58.88
Carbonate of lime	6.32	9.05	9.02
Phosphate of magnesia	1.94	.69	1.17
Salts	1.22	1.78	0.92
Cartilage	47.30	34.16	{ 28.00 2.01

CETACEA.

PINNIPEDIA.

Dolphin.

Common seal.

	Costa.	Vertebrae.	Os occipitis.	Maxilla inf.
Phosphate of lime with a little fluoride of calcium }	53.59	52.51	59.77	54.11
Carbonate of lime	9.99	9.37	7.23	7.20
Phosphate of magnesia	1.10	0.98	1.18	0.93
Salts	3.24	1.24	1.43	1.22
Cartilage	30.46	33.97	30.11	35.24
Fat	—	—	1.28	1.30

FALCULATA.

Cat aged 6 years.

Wolf.

	Humerus.	Verteb.	Os occip.	Femur.	Humerus.	Costa.	Verteb.
Phosphate of lime with a little fluoride of calcium }	59.30	48.01	51.70	57.87	55.36	51.76	48.72

¹ Von Bibra likewise analyzed separately the compact and spongy substance of the femur of a horse aged 12 years, and obtained the following results:

	Compact substance.	Spongy substance.
Phosphate of lime with a little fluoride of calcium	54.65	41.14
Carbonate of lime	11.74	18.93
Phosphate of magnesia	1.48	1.33
Salts	0.86	0.94
Cartilage	31.27	37.67

² These analyses were made by Valentin.

ANIMAL BODY.

Carbonate of lime	10.69	8.44	10.13	11.09	11.76	10.90	10.03
Phosphate of magnesia	1.70	0.97	1.07	1.13	1.97	1.00	0.68
Salts	0.40	0.39	0.37	1.03	0.99	0.90	0.91
Cartilage	27.91	40.79	35.63	27.44	29.51	33.78	37.53
Fat	0.70	1.40	0.90	1.45	1.31	1.66	1.83

VOLANTIA.

	Common bat.	
Phosphate of lime with a little fluoride of calcium		
Carbonate of lime		
Phosphate of magnesia		
Salts		
Cartilage		
Fat		
	Femur.	Humerus.
	57.45	56.90
	4.77	6.00
	1.03	1.00
	0.75	0.80
	34.20	34.27
	1.80	1.03

POLICATA.

Cebus Capucinus (Capuchin ape.)

	Femur.	Humerus.	Vertebrae.	Costa.	Scapula.	Ost. illi.
Phosphate of lime with a little fluoride of calcium	54.33	51.87	50.43	51.54	50.94	46.63
Carbonate of lime	7.99	7.33	6.92	7.00	7.31	6.03
Phosphate of magnesia	1.58	1.73	1.33	1.15	1.20	1.07
Salts	0.69	0.93	0.92	0.87	0.91	0.90
Cartilage	34.01	37.18	39.04	38.37	39.33	44.16
Fat	1.20	0.97	1.36	1.07	1.01	1.21

BIRDS.

	Thrush.		Sparrow 6 days old.	Sparrow (aged.)	
	Femur.	Humerus.	Femur, tibia, & humerus together.	Femur.	Humerus.
Phosphate of lime with a little fluoride of calcium	58.64	63.65	39.78	59.46	60.04
Carbonate of lime	5.07	6.05	3.62	8.88	9.97
Phosphate of magnesia	0.83	0.90	0.40	1.03	1.19
Salts	0.77	0.84	0.30	0.90	0.90
Cartilage	33.43	28.03	55.80	27.20	26.14
Fat	1.26	1.54	0.10	2.53	1.86

REPTILES.

	Salamandra terrestris.		Rana esculenta.	Coluber natrix.	
	Mixed bones.	Femur.	Tibia.	Vertebrae.	Vertebrae.
Phosphate of lime with a little fluoride of calcium	53.69	59.48	59.73	59.41	47.58
Carbonate of lime	2.46	2.25	2.24	7.82	6.92
Phosphate of magnesia	1.07	0.99	0.97	1.00	1.11
Salts of soda	0.83	1.78	1.90	0.73	0.90
Cartilage	39.64	30.19	29.16	24.93	36.18
Fat	3.12	5.31	6.00	6.11	7.37

FISHES.

	Eel.	Pike.	Salmon.	Cod.	
	Vertebrae.	Vertebrae.	Vertebrae.	Vertebrae.	Ost. occip.
Phosphate of lime with a little fluoride of calcium	32.46	38.70	36.64	57.65	61.15
Carbonate of lime	3.64	14.30	1.01	4.81	5.20
Sulphate of lime	1.09				
Phosphate of magnesia	0.78	0.81	0.70	2.30	2.02
Sulphate of soda	0.63				
Carbonate of soda and chloride of sodium	0.66	0.97	0.83	1.00	1.03
Cartilage	36.99	32.72	21.80	31.90	27.89
Fat	23.55	12.60	38.62	2.34	2.11

We have selected these individual cases from 143 analyses of the bones of mammalia (independently of man,) 151 of birds, 31 of reptiles, and 23 of fishes.]

Morbid bones.

[*Rachitis.* The bones in this disease have been analyzed by several chemists.

Lehmann examined the tibiae of three rachitic children. He found:

		1.	2.	3.
Phosphate of lime	-	32.04	26.94	28.13
Carbonate of lime	-	4.01	4.88	3.75
Phosphate of magnesia	-	0.98	0.81	0.67
Chloride of sodium	-	0.21	0.27	0.28
Soda	-	0.54	0.81	0.73
Cartilage	-	54.14	60.14	58.77
Fat	-	5.84	6.22	6.94

Ragsky found in the scapula and humerus of a rachitic child:

Phosphates of lime and magnesia	-	-	15.60
Carbonate of lime	-	-	2.66
Soluble salts	-	-	0.62
Cartilage, vessels, and fat	-	-	81.12

In the ulna of a child aged 5—6 years, Von Bibra found:

Phosphate of lime with a little fluoride of calcium	-	47.83
Carbonate of lime	-	7.42
Phosphate of magnesia	-	1.23
Salts	-	1.62
Cartilage	-	35.61
Fat	-	6.09

Osteomalacia. Several analyses of bone in this disease are on record.

	Vertebra. (Boston.)	Vertebra. (Prösch.)	Costa. (Prösch.)
Phosphate of lime	-	13.60	13.25
Phosphate of magnesia	-	0.62	—
Carbonate of lime	-	1.13	5.95
Sulphate of lime and phosphate of soda	-	4.70	0.90
Cartilage	-	79.75	74.64
Fat	-	—	5.26
			11.63

An analysis by Bogner of the bones of a man aged 32 years, who died from osteomalacia, yielded the following results:

	Scapula.	Radius.	Femur.	Patella.
Phosphate of lime	-	26.92	28.11	23.50
Carbonate of lime	-	0.98	1.07	0.97
Phosphate of magnesia	-	5.40	6.35	5.07
Cartilage and vessels	-	65.85	63.42	69.77
Soda, iron, and loss	-	0.85	1.05	0.69
				0.64

Ragsky has analyzed bone in this disease. He found in a rib:

Phosphates of lime and magnesia	-	-	17.48
Carbonate of lime and salts	-	-	6.33
Cartilage, vessels, and fat	-	-	76.20

After the removal of the fat, Lehmann found:

	1.	2.	3.
Phosphate of lime	-	36.863	31.718
Other salts	-	4.968	7.913
Cartilage	-	58.169	60.369
			58.445

and in two other cases of osteomalacia occurring in persons aged about 40 years, the same chemist found:

		1.		2.	
		Femur.	Cossa.	Femur.	Cossa.
Phosphate of lime	-	17.56	21.02	18.63	19.14
Carbonate of lime	-	3.04	3.27	3.63	4.08
Phosphate of magnesia	-	0.23	0.44	0.54	0.66
Soluble salts	-	0.37	0.63	0.43	0.41
Cartilage	-	49.63	50.48	41.54	42.43
Fat	-	29.18	23.13	34.15	39.65

The three following analyses of bone in this disease were made by Von Bibra:

	Tibia of a woman aged 73 years.	Femur of a woman 63 years.	Femur of a man aged 60 years.
Phosphate of lime with a little fluoride of calcium	55.01	46.79	53.25
Carbonate of lime	4.94	6.37	7.49
Phosphate of magnesia	2.01	1.20	1.22
Salts	0.31	1.37	1.35
Cartilage	29.17	30.99	39.64
Fat	8.56	13.98	4.15

Marchand found the bones of the child whose case is noticed in p. 512 of this volume, composed in the following manner:

	Vertebra.	Radius.	Femur.	Stomach.
Phosphate of lime	-	12.56	15.11	21.35
Phosphate of magnesia	-	0.92	0.78	0.72
Carbonate of lime	-	3.20	3.15	3.00
Sulphate of lime }	-	0.98	1.00	1.02
Sulphate of soda }	-	-	-	1.68
Fluoride of calcium, chloride of sodium, iron, and less	1.00	1.20	1.00	2.61
Cartilage	-	75.22	71.26	79.00
Fat	-	6.12	7.50	9.94

The cartilage yielded neither glutin nor chondrin.

Arthritis. Marchand analyzed the upper part of the femur, and the bones of the fore-arm of a person with abundant tophaceous deposits in the knee- and elbow-joints. He found in these bones:

	Femur.	Radius & ulna.
Phosphate of lime	-	42.12
Carbonate of lime	-	8.24
Phosphate of magnesia	-	1.01
Animal matter	-	46.39
Fluoride of calcium, soda, chloride of sodium, and less	2.31	45.96
		1.37

Lehmann analyzed the bones of three persons with chronic gout; their ages varied from 40 to 50 years. He found:

	1.	2.	3.
Phosphate of lime	36.16	35.63	37.93
Carbonate of lime	8.41	9.62	8.99
Phosphate of magnesia	1.31	1.05	1.13
Soluble salts	2.93	2.03	1.69
Cartilage	38.14	38.26	40.03
Fat	12.11	13.37	9.16

Caries. Valentin has analyzed carious bones, and likewise an osteophyte incrustation surrounding the carious tibia of a man aged 38 years.

		Tibia of a man aged 38 years.	Vertebrae of a man aged 90 years.
Phosphate of lime	-	34.383	33.914
Carbonate of lime	-	6.636	7.602
Phosphate of magnesia	-	1.182	0.389
Chloride of sodium }	-	1.919	{ 3.157
Carbonate of soda }	-		{ 0.118
Organic constituents	-	55.880	54.830
		External condyle of the femur of a girl.	Head of tibia of the same individual.
Phosphate of lime	-	39.393	45.451
Carbonate of lime	-	4.620	5.683
Phosphate of magnesia	-	0.520	1.180
Chloride of sodium	-	0.424	1.620
Carbonate of soda	-	0.647	0.446
Organic constituents	-	54.396	45.620

In the osteophyte incrustation there were contained:

Phosphate of lime	-	-	-	-	-	29.424
Carbonate of lime	-	-	-	-	-	4.201
Phosphate of magnesia	-	-	-	-	-	0.317
Chloride of sodium	-	-	-	-	-	5.556
Carbonate of soda	-	-	-	-	-	1.117
Organic matters	-	-	-	-	-	59.370

Von Bibra has also made several analyses of carious bones:

Bones of the hand of a man.			
	Metacarpal bone.	Its upper articulating portion.	Phalanx.
Phosphate of lime with a little fluoride of calcium }	49.77	31.36	49.36
Carbonate of lime	7.24	4.07	8.08
Phosphate of magnesia	1.11	0.83	0.98
Salts	0.30	0.30	0.40
Cartilage	37.97	59.36	37.47
Fat	3.61	4.08	3.71

Femur of a man.		
Diseased portion.	Mass of the bone.	
Phosphate of lime with a little fluoride of calcium }	51.53	54.98
Carbonate of lime	5.44	5.97
Phosphate of magnesia	3.43	3.70
Salts	0.91	0.89
Cartilage	35.69	31.44
Fat	3.00	3.02

Palate bone of a woman aged 40 years, with inveterate syphilis.
The portion submitted to analysis was thrown
off during her lifetime, and weighed 16.5 grains.

Phosphate of lime with fluoride of calcium	-	-	-	45.14
Carbonate of lime	-	-	-	5.03
Phosphate of magnesia	-	-	-	2.40
Salts	-	-	-	0.62
Cartilage	-	-	-	42.34
Fat	-	-	-	4.27

Tibia of a man aged 25 years.	Tarsus of a man aged 40 or 50 years.
Phosphate of lime with fluoride of calcium	47.79
Carbonate of lime	6.44
Phosphate of magnesia	1.30
Salts	2.00
Cartilage	29.57
Fat	13.60

	Nasal bone of a girl aged 15 years.	Lumbar vertebrae of a woman aged 40 years
Phosphate of lime, with } fluoride of calcium }	45.77	44.05
Carbonate of lime	3.77	3.45
Phosphate of magnesia	1.45	1.08
Salts	1.10	1.70
Cartilage	38.62	41.42
Fat	9.29	8.36

Necrosis. The following analysis was made by Von Bibra:

	Phalanx of a man aged 40-50 years.
Phosphate of lime with fluoride of calcium	-
Carbonate of lime	72.63
Phosphate of magnesia	-
Salts	4.03
Cartilage	1.23
Fat	0.61
	19.58
	1.22

This small amount of organic matter is not characteristic of necrotic bone, for in two minute portions thrown off after fractures Von Bibra found:

	1.	2.
Organic matter	37.87	31.58
Inorganic matter	60.77	67.33
Fat	1.36	1.09

Osteoporosis. Ragsky has analyzed a specimen of osteoporosis growing on the cranium of an aged person. It yielded gelatin when boiled. It contained:

Phosphates of lime and magnesia	-	-	-	-	55.80
Carbonate of lime and salts	-	-	-	-	5.69
Cartilage, vessels, and fat	-	-	-	-	39.61

Sclerosis. Ragsky has analyzed bone in several cases of this affection.

Simple sclerosis of the cranium of a madman.		
Phosphate of lime with fluoride of calcium	-	54.10
Carbonate of lime	-	10.45
Phosphate of magnesia	-	1.00
Soluble salts	-	1.04
Cartilage and vessels	-	33.41
Sclerosis consecutive on osteoporosis. (The bone not specified.)		
Phosphate of lime and magnesia	-	48.20
Carbonate of lime	-	7.45
Soluble salts	-	0.25
Cartilage, fat, and vessels	-	44.10
Sclerosis more highly developed.		
Phosphates of lime and magnesia	-	50.29
Carbonate of lime and soluble salts	-	7.20
Cartilage and vessels	-	42.51

¹ In the cavity of this bone, produced by the caries, there was a thick, reddish yellow matter, like inspissated pus. It consisted of 81.3 parts of water and volatile matter, and 18.7 of solid constituents. The latter contained in 100 parts:

Albuminous matter	-	19.7
Alcohol extract and lactates	-	0.9
Water-extract	-	9.4
Shreds of cartilage	-	51.0
Fat	-	7.2
Fixed salts	-	18.8 containing 90% of phosphate of lime.

Sclerosis in the highest degree.				
Phosphates of lime and magnesia	-	-	55-52	
Carbonate of lime	-	-	5-95	
Soluble salts	-	-	0-26	
Cartilage and vessels	-	-	38-27	
Sclerosis of the femur.				
Phosphates of lime and magnesia	-	-	53-21	
Carbonate of lime	-	-	8-30	
Cartilage and vessels	-	-	38-49	
Syphilitic sclerosis, highly developed.				
Phosphates of lime and magnesia	-	-	57-20	
Carbonate of lime	-	-	6-50	
Cartilage and vessels	-	-	36-30	

Exostosis. Lassaigne has analyzed an exostosis, the thickened bone to which it was attached, and a healthy portion of the same bone.

	Thickened bone.	Healthy bone.	Exostosis.
Phosphate of lime	-	36-3	41-6
Carbonate of lime	-	6-5	8-2
Soluble salts	-	14-2	8-6
Organic matter	-	43-0	41-6

Von Bibra has analyzed an exostosis on the humerus of a dog. In the second analysis the composition of the healthy radius and ulna are represented.

	1. Exostosis.	2. Radius and ulna.
Phosphate of lime with fluoride of calcium	47-99	60-95
Carbonate of lime	1-00	2-84
Phosphate of magnesia	1-55	1-39
Salts	0-91	0-93
Cartilage	45-74	32-88
Fat	2-81	1-01

We observe in both these cases that the exostosis contains a larger amount of organic matter than healthy bone.]

I have analyzed a remarkable osteoid tumour that formed on the knee of a leucophlegmatic boy aged 14 years, who was suffering from oedema. The tumour was ten inches long and twenty-five broad, and could be hardly half spanned with both hands. The limb was amputated, and the tumour examined. I analyzed separately three portions of the tumour, one hard and bony, a second softer, and a third perfectly soft. On exposing them to heat on an oil-bath, the first became white and earthy, while the other portions assumed a horny appearance.

Ether took up a dirty yellow, non-phosphorized fat.

The three specimens yielded on analysis:

	Anal. 155.	Anal. 156.	Anal. 157.
Phosphate of lime	-	35-65	8-00
Carbonate of lime	-	2-70	0-62
Phosphate of magnesia	-	0-58	0-21
Soluble salts	-	0-52 }	
Chloride of sodium	-	0-26 }	0-39
Fat	-	1-16	3-61
Cartilage and vessels	-	58-91	87-04

The proportions of the fixed salts to each other in these cases, and as they occur in normal bone, are exhibited in the following table:

	1.	2.	3.	Healthy bone.
Phosphate of lime	89.7	86.5	86.9	79.4
Phosphate of magnesia	1.5	1.9	—	1.7
Carbonate of lime	6.8	6.6	6.0	16.9
Soluble salts	0.7	1.4	6.8	{ 1.4 Chloride of sodium } 0.4
	1.3			

The most striking peculiarity is the relative diminution of the carbonate of lime.

[*Callus* has been analyzed by Lassaigne and Von Bibra.

Lassaigne examined the outer and inner portions of a mass of callus. He found:

	External portion.	Internal portion.
Phosphate of lime	—	33.3
Carbonate of lime	—	5.7
Soluble salts	—	11.3
Animal matter	—	50.0

The following analyses were made by Von Bibra:

	Callus from the tibia of a hare.	Callus from the rib of a horse.
Phosphate of lime with fluoride of calcium	32.62	43.90
Carbonate of lime	1.01	5.69
Phosphate of magnesia	1.13	1.20
Salts	1.79	0.74
Cartilage	61.41	46.97
Fat	2.04	1.50

Hence callus does not contain so large an amount of earthy salts as true bone.]

The teeth.

The teeth, like the bones, consist of phosphate and carbonate of lime, fluoride of calcium and cartilage. The bony matter of the tooth is covered superiorly with enamel, while the fangs are coated with cement or cortical matter, which likewise overlays the enamel of the crown. Of the three constituents of tooth, enamel, bone (dentine,) and cortical substance, the last is the poorest in inorganic matter. Lassaigne found therein:

Organic matter	—	—	—	42.18
Phosphate of lime	—	—	—	53.64
Carbonate of lime	—	—	—	3.98

The osseous portion (dentine) hardly differs from true bone. Berzelius found therein:

Cartilage and vessels	—	—	—	28.0
Phosphate of lime with fluoride of calcium	—	—	—	64.3
Carbonate of lime	—	—	—	5.3
Phosphate of magnesia	—	—	—	1.0
Soda, with chloride of sodium	—	—	—	1.1

Pepys found:

Cartilage	—	—	—	28.0
Phosphate of lime	—	—	—	58.0
Carbonate of lime	—	—	—	4.0
Water and loss	—	—	—	10.0

From analyses made by Lassaigne of human teeth at different ages, it appears that the phosphate of lime gradually increases, and that there is a corresponding diminution of the carbonate.

		Organic matter.	Phosphate of lime.	Carbonate of lime.
Tooth of a child one day old	-	35.00	51.00	14.00
" of a child aged 6 years	-	28.57	60.01	11.42
" of an adult man	-	29.00	61.00	10.00
" of a man aged 81 years	-	33.00	66.00	1.00

In the enamel of human teeth, Berzelius found:

Phosphate of lime with fluoride of calcium	-	88.5
Carbonate of lime	--	8.0
Phosphate of magnesia	-	1.5
Membrane, alkali, and water	-	2.0

So that this substance seems almost destitute of organic combination.

[Von Bibra has made the following analyses of human teeth:

	Molar tooth of a woman aged 25 years.		Molar tooth of an adult male.	
	Enamel.	Osseous portion.	Enamel.	Osseous portion.
Phosphate of lime with a little fluoride of calcium	81.63	67.54	89.82	66.72
Carbonate of lime	8.88	7.97	4.37	3.36
Phosphate of magnesia	2.55	2.49	1.34	1.08
Salts	0.97	1.00	0.88	0.83
Cartilage	5.97	20.42	3.39	27.61
Fat	a trace	0.58	0.20	0.40

For a series of analyses of the teeth of the lower animals I must refer the reader to the original work, (*Chemische Untersuchungen über die Knochen und Zähne des Menschen und der Wirbeltiere,*) which may be regarded as a perfect monograph on the subject of which it treats.]

Cartilage.

The cartilages are invested with a peculiar membrane, the perichondrium; they are not so hard as bone, but are more elastic and supple. They are usually divided into two classes, the true and the fibrous cartilages. In addition to their respective microscopic appearances, they present well-marked chemical differences. The true cartilages dissolve almost entirely in water, and yield chondrin (see Introduction, p. 32.) If, however, the boiling is interrupted before the solution is perfectly effected, it will be found that the cells have remained almost unchanged, and that only the basic substance has been dissolved. Even when true cartilage is perfectly dissolved the solution is somewhat turbid, owing, probably, to a partial change in the cells. Fibrous cartilage, in which the cells form the preponderating mass when continuously boiled for forty-eight hours, yields only a small quantity of extract, which exhibits all the ordinary reactions of chondrin, but does not gelatinize. The inorganic constituents of cartilage form only a small portion of their mass; Fromherz and Gugert¹ found in the costal cartilage of a man aged 20 years, 3.402% of fixed salts, associated in the following proportions:

¹ Schweiger's Journal, vol. 50, p. 187.

Carbonate of soda	-	-	35.1
Sulphate of soda	-	-	24.2
Chloride of sodium	-	-	8.2
Phosphate of soda	-	-	0.9
Sulphate of potash	-	-	1.2
Carbonate of lime	-	-	18.3
Phosphate of lime	-	-	4.1
Phosphate of magnesia	-	-	6.9
Peroxide of iron and less	-	-	0.9

In the corresponding cartilage of a woman aged 63 years, the same salts were observed, but to a smaller amount: there was also a larger amount of phosphate than of carbonate of lime.

The following analyses of cartilage are extracted from Von Bi-bra's work:—

	Costal cartilage of a child aged 6 months. 100 parts yielded	Ditto of a child aged 3 years. 100 parts yielded
2.24 of the following ash: 3.00 of the following ash:		
Phosphate of lime	-	20.66
Sulphate of lime	-	50.68
Phosphate of magnesia	-	9.68
Sulphate of soda	-	9.21
Phosphate of soda }	-	a trace
Carbonate of soda }	-	{ 3.00
Chloride of sodium	-	9.37
Costal cartilage of a girl aged 19 years.		
Ditto of a woman aged 25 years. 100 parts yielded		
Ditto of a man aged 40 years.		
7.29 of the following ash: 3.92 of the following ash: 6.1 of the following ash:		
Phosphate of lime	5.36	6.33
Sulphate of lime	92.41	87.32
Phosphate of magnesia	0.99	4.10
Sulphate of soda	1.24	0.95
Phosphate of soda	a trace	a trace
Chloride of sodium	a trace	1.30
Carbonate of soda	—	a trace
Carbonate of lime	—	—

Synovia.

The synovial fluid is viscid, transparent, of a yellow or reddish colour, faintly saline, and resembles in its odour the serum of the blood. A specimen of this fluid, analyzed by John, contained:

Water	-	-	-	-	-	92.80
Albumen	-	-	-	-	-	6.40
Extractive matter, with muriate and carbonate of soda	-	-	-	-	-	0.60
Phosphate of lime	-	-	-	-	-	0.15

Cellular Tissue, Tendons, Ligaments, Skin, Hair.

These may be classified together as tissues that yield gelatin. They are distinguished more by their microscopical than their chemical characters, and we may refer to Henle for an excellent account of their minute structure. The elements of cellular or combining tissue (*Bindegewebe*) in whatever part of the body it occurs are long, fine, hyaline fibrillæ or cylinders, varying in diameter from .0003 to .0008 of a line, and lying in close apposition. They are firm and elas-

tic, are not changed by cold water, nor dissolved by acetic acid; the latter reagent renders them gelatinous and tough, but takes up no protein-compound. The organs containing this tissue diminish when boiled, become harder and more rigid, but ultimately soften and dissolve into gelatin, forming a solution that stiffens on cooling. Alcohol, ether, and oil exert no action on cellular tissue, even when aided by heat.

Tendons swell on being boiled, become yellow, and are gradually converted into gelatin. The solution is turbid in consequence of the flocculent appearance presented by minute vessels in suspension. In concentrated acetic acid they swell, become transparent and gelatinous, and in this state readily dissolve in hot water, from which neither an alkali nor ferrocyanide of potassium throws down any precipitate.

Ligaments consist partly of cellular and partly of elastic tissue, and these two structures present both chemical and physiological differences. True elastic tissue is not changed by acetic acid, is not converted by boiling into gelatin, but with the aid of heat dissolves readily in dilute mineral acids, from which it is not precipitated by ferrocyanide of potassium. As illustrations of the true elastic tissue, we may refer to the ligamenta flava between the vertebræ and the ligamentum nuchæ in the ruminants.

The *cutis*, or true skin, is a contractile cellular tissue, convertible, by boiling, into gelatin. It is permeated by a fluid, and contains also cellular tissue and vessels. Wienholt has endeavoured to determine their relative proportions; he obtained:

Cutaneous tissue (including cellular tissue and vessels)	:	32·53
Water	:	57·50
in which were dissolved:		
Albumen	:	1·54
Alcohol-extract	:	0·83
Water-extract	:	7·60

The skins of different animals require boiling for different lengths of time in order to be converted into gelatin, and the change is effected more rapidly in young than in old animals.

The conversion of the *cutis* into gelatin is much facilitated by the action of dilute alkalies or acids; it then takes place at an ordinary temperature. The skin combines with basic sulphate of iron, and with bichloride of mercury, when immersed in solutions of those salts, and it then resists putrefaction. It likewise combines with tannin, forming a substance insoluble in water, and no longer tending to putrefaction (leather.)

The *epidermis* is affected by strong mineral acids: concentrated sulphuric acid dissolves it, as also do the caustic alkalies. Many metallic salts combine with and colour it. The terchloride of gold communicates a purple, nitrate of the protoxide of mercury a reddish brown, and nitrate of silver a black colour: the volatile oxide of chrome (?) exerts a similar effect, and even the alkaline sulphurets communicate a brown or black colour to it.

[The hair has recently been examined by Scherer and Van Laer.¹ By treating the hair with spirit, ether, and water, there were removed margarin and margaric acid, olein, a brown matter soluble in water, chlorides of sodium and potassium, and lactate of ammonia.

By ultimate analysis there were then obtained:

	Scherer.				Van Laer.	
	1.	2.	3.	4.	1.	2.
Carbon	51.529	50.652	50.622	49.935	50.12	50.65
Hydrogen	6.687	6.766	6.613	6.631	6.33	6.36
Oxygen }	23.848	24.643	24.220	25.498	21.03	20.61
Sulphur }					4.99	5.00
Nitrogen	17.963	17.963	17.963	17.963	17.52	17.14

No. 1 was hair of the beard; 2, of the head of a fair person; 3, was brown hair; and 4, black hair from a Mexican. The ash in 1 amounted to 0.72%; in 2, to 0.8%; and in 4, to 2.0%.

According to Van Laer, the inorganic constituents in 100 parts are:

Colour.	Ash.	Soluble portion.	Peroxide of iron.	Insoluble portion.
Brown hair	. . .	0.54	0.17	0.312
"	. . .	1.10	0.61	0.200
"	. . .	0.32	—	—
Black hair	. . .	1.02	0.29	0.516
"	. . .	1.15	—	—
Red hair	. . .	1.30	0.93	0.170
"	. . .	0.54	0.27	0.200
"	. . .	1.85	—	—
Gray hair	. . .	1.00	0.24	0.232
"	. . .	0.75	—	0.528

The soluble portion consisted of chloride of sodium, sulphate of lime, and sulphate of magnesia; the insoluble constituents were phosphate of lime and silica.

From Van Laer's investigations it appears that the hair consists essentially of:

1. A connecting medium consisting of a tissue yielding gelatin and represented by the formula $C_{12}H_{10}N_3O_5$;—and
2. Of bisulphuret of protein, $C_{40}H_{31}N_5O_{12}S_2$.

The large amount of sulphur in hair (averaging 5%) is the cause of its colour being affected by various metallic salts. As there is no constant difference in the results obtained by the analysis of hair of various tints, it is to be presumed that the colour is dependent on peculiar arrangements of the ultimate particles.

Hair further contains about 0.4% of peroxide of iron, which is supposed by Van Laer to be chemically combined with the protein.]

Crystalline Lens and Fluids of the Eye.

The crystalline lens is insoluble in boiling water, spirit, and acids; it does not even communicate any turbidity to them; hence it consists neither of cellular nor elastic tissue, but is a distinct substance, approximating possibly towards horny tissue. The membrana Demoursii, the third layer of the cornea, possesses similar properties,

¹ Scheik. Onderzoek, 2^o St. p. 75.

while the true horny layer which lies between the external layer of epithelium and the membrana Demoursii appears to be fibrous, and is converted by boiling into chondrin. The crystalline lens itself possesses a peculiar and very regular fibrous arrangement. Chevenix found the specific gravity of the human lens to be 1079, and that of the sheep 1180. I have observed that the crystalline lens in young animals is softer, and less resisting than at a more advanced age.

With respect to the chemical composition of the lens, I find that, in addition to albumen, it contains a substance closely resembling casein, to which I apply the term crystallin. I reduce the lens to a pulpy mass, stir it with water, and then heat the mixture to the boiling point: the albumen coagulates, while the crystallin does not coagulate, but is entangled in the albumen. In order to separate them I evaporate to dryness, pulverize the white residue, and boil it, first with ether in order to separate fat, and then with spirit of .915 as long as any thing continues to be taken up. The albumen rapidly sinks from the hot, clear, spirituous solution, and the supernatant fluid which must be decanted from the sediment, soon begins to become turbid from the separation of numerous flocculi of crystallin. I evaporate to a slight residue, and then precipitate the crystallin by strong alcohol, in which it is only slightly soluble. The lactates and chloride of sodium remain dissolved in the alcohol. In this manner I analyzed the crystalline lens of the ox and the horse.

		Anal. 158. Crystalline lens of ox.	Anal. 159. Ditto of horse.
Water	-	65.762	60.000
Albumen	-	23.290	25.531
Crystallin	-	10.480	14.200
Fat	-	0.045	0.142
Extractive matter with chloride of sodium and lactates	{	0.495	0.426

Berzelius has not separated the albumen and crystallin: in other respects his analysis approximates to mine, as far as the amount of the protein-compounds is concerned.

He found it composed of:

Water	-	-	-	-	58.0
Protein-compounds	-	-	-	-	35.9
Alcohol-extract with salts	-	-	-	-	2.4
Water-extract with traces of salts	-	-	-	-	1.3
Cell-membrane	-	-	-	-	2.4

It has been shown by Wurzer and Lassaigne, that when the lens is opaque (in cases of cataract) it contains an excess of phosphate of lime. This may be the cause of the opacity, or it may be due to the coagulation of the protein-compounds by the presence of a free acid. Wurzer determined the composition of an opaque lens from a bear. It contained (after the removal of the water:)

Phosphate of lime	-	-	-	-	68.9
Carbonate of lime	-	-	-	-	12.6
Carbonate of magnesia	-	-	-	-	3.6
Peroxides of iron and manganese	-	-	-	-	0.7

Mucus (?)					7·5
Phosphate of lime with an animal matter					2·1
Chloride of sodium with animal matter					3·2
Solid fat					1·1

Lassaigne analyzed an opaque lens from a horse. It contained:

Coagulated albumen				29·3
Phosphate of lime				57·4
Carbonate of lime				1·6
Soluble salts and other matters				17·7

The vitreous humour is perfectly clear and contains a very small amount of solid constituents in solution. It is enclosed in numerous compartments by a very delicate transparent membrane. On removing it by gentle pressure from this membrane, and evaporating it to dryness, it yields only 0·16% of a colourless residue consisting for the most part of chloride of sodium. Berzelius obtained from it:

Water				98·40
Albumen				0·16
Chloride of sodium with a little extractive matter				1·42
A substance soluble in water				0·02

The aqueous humour contains, according to Berzelius:

Water			98·10
Albumen			a mere trace
Chloride of sodium with a little alcohol-extract			1·15
Extractive matter soluble only in water			0·75

The Arteries and Veins.

Very little is known with certainty regarding the chemical composition of the different coats of the blood-vessels, but their microscopic characters have been thoroughly examined by Henle. Berzelius has shown that the middle coat of the arteries belongs to the elastic tissues; Eulenberg, on the other hand, asserts that from 30 grains of dried arterial membrane (middle coat) he obtained, by three successive boilings, occupying in all 120 hours, 11 grains of dried substance which dissolved in water and gelatinized on cooling. Valentin found that an acetic-acid solution of arterial membrane is precipitated by ferrocyanide of potassium, and I have obtained a solution of the middle coat (by boiling it in water for ten hours) which is strongly precipitable by acetic acid. The greater part of the precipitate dissolves in an excess of the acid, and is again thrown down by ferrocyanide of potassium: tannin, bichloride of mercury, and basic acetate of lead cause considerable turbidity.

The Muscles.

Muscular fibre is chemically distinguished from the fibre of cellular tissue by the circumstance that it does not yield gelatin by prolonged boiling in water, but dissolves in acetic acid, from which it may be precipitated by ferrocyanide of potassium, showing that it belongs to the protein-compounds. The microscopic characters of the various species of muscular fibre have been well described by Henle.

In consequence of the difficulty that exists in separating muscular fibre from cellular tissue, vessels, and nerves, it is impossible to speak with certainty respecting the behaviour of pure muscle towards reagents. If very small pieces of muscle are freed as much as possible from fat and cellular substance, and immersed in water, blood, colouring matter, and the extractive matter with which muscle abounds, are gradually taken up, and colourless muscular fibres are left.

Cold water and alcohol produce little effect on them, but in boiling water they first contract and become firm, and subsequently soften. Concentrated acetic acid dissolves them; in the dilute acid they swell and assume a transparent fibrous appearance. The alkaline carbonates increase their firmness. Solutions of muscular fibre in dilute acids are precipitated by ferrocyanide of potassium and tannin in a precisely similar manner to acid solutions of fibrin. Dried muscular fibre may be easily pulverized; in that condition it resembles the whole class of protein-compounds in exhibiting strong positively electrical properties.

On making incisions into the warm flesh of an animal just killed, we obtain, by pressure, an acid fluid which rapidly coagulates in consequence of the presence of a little fibrin: if the flesh has been kept for some time the fluid obtained by pressure no longer coagulates, although it exhibits an acid reaction. No quantitative analysis of human flesh¹ has yet been made, but the flesh of several animals has recently been submitted to analysis. The amount of water averages about 80%, and the greater part of the solid residue consists of fibrin; the other constituents, albumen, hæmato-globulin, fat, extractive matters, lactic acid, the lactates and other salts occur in the expressed juice. The proportions of these constituents have been determined by Berzelius, Braconnot, Schlossberger, Schultz, [and Marchand.] In the flesh of oxen they found:

	Berzelius.	Braconnot.	Schlossberger.	Schultz.	Marchand.
Water	77.17	77.03	77.50	77.50	76.60
Fibrin, cells, vessels & nerves	17.70	18.18	17.50	15.00	18.00
Albumen & hæmato-globulin	2.20	2.70	2.20	4.30	2.50
Alcohol-extract and salts	1.80	1.94	1.50	1.32	1.70
Water-extract and salts	1.05	1.15	1.30	1.80	1.10
Phosphate of lime with albumen	0.08	—	traces	—	0.10
Fat and loss	—	—	—	0.08	—

[The dried muscular flesh of the ox has been analyzed by Playfair and Böckmann, and found to be identical in its composition with dried blood:

¹ [The following analyses of human flesh by Marchand (*Lehrbuch der Physiologischen Chemie*, p. 156) and L'Heretier (*Traité de Chimie Pathologique*, p. 660) have appeared since the publication of Simon's Chemistry. The flesh in the first analysis was taken from the upper portion of the arm of a man who died from diseased liver.

	Marchand.	L'Heretier..
Water and loss	78.00	77.10
Matter insoluble in cold water	17.00	15.80
Soluble albumen with colouring matter	2.30	3.40
Alcohol-extract with salts	1.60	1.20
Water-extract with salts	1.00	2.50
Phosphate of lime, with albumen	0.10	—]

ANIMAL BODY.

	Flesh [beef.]		Ox-blood.	
	Playfair.	Bickmann.	Playfair.	Bickmann.
Carbon	51.63	51.69	51.95	51.96
Hydrogen	7.57	7.59	7.17	7.33
Nitrogen	15.01	15.05	15.07	15.08
Oxygen	21.37	21.24	21.39	21.21
Ashes	4.23	4.23	4.42	4.42

Deducting the ashes or inorganic matter, the composition of the organic part is:

Carbon	-	54.12	54.18	54.19	54.20
Hydrogen	-	7.69	7.93	7.48	7.65
Nitrogen	-	15.67	15.71	15.73	15.73
Oxygen	-	22.32	22.18	22.31	22.12

which corresponds to the formula $C_{48}H_{39}N_6O_{15}$.

In 100 parts of the ashes yielded by the incineration of ox-flesh Enderlin found:

Tribasic phosphate of soda (3 NaO, PO ₄)	-	45.100	91.036 soluble salts
Chlorides of sodium and potassium	-	45.936	
Phosphates of lime, magnesia, and peroxide of iron	-	6.640 insoluble salts	
Loss	-	2.124	
		100.000]	

The following analyses of the flesh of other animals have been made by Schlossberger:

	Calf.		Swine.	Roe.	Pigeon.	Chicken.	Carp.	Trot.
	1.	2.						
Water	79.7	78.2	78.3	76.9	76.0	77.3	80.1	80.5
Muscular fibre and vessels	15.0	16.2	16.8	18.0	17.0	16.5	12.0	11.1
Albumen and haemato-globulin	3.2	2.6	2.4	3.3	4.5	3.0	5.2	4.4
Alcohol-extract with salts	1.1	1.4	1.7	2.4	{ 1.0	1.4	1.0	1.6
Water-extract with salts	1.0	1.6	0.8			1.5	1.2	1.7
Phosphate of lime with albumen	0.1	traces	traces	0.4	—	0.6	—	2.2

The analyses of Schultz correspond in many points with those of Schlossberger. In calves' flesh Schultz found a little more animal fibre than Schlossberger: in the flesh of a pig four weeks old Schultz found 21.1 parts of muscular fibre and 3.45 of albumen and haemato-globulin; and in the flesh of a pig two years and a half old he found 20.3 parts of the former and 4.2 of the latter. Schultz also found that the amount of muscular fibre was less in the flesh of fishes than in that of the mammalia: thus in the flesh of cyprinus nasus and cyprinus barbus the proportions of fibre were 13.5 and 17.18 respectively.

[We may take this opportunity of noticing an interesting paper by Helmholtz,¹ on the consumption of tissue during muscular action.

Powerful muscular contractions were induced by passing an electric current through the amputated leg of a frog as long as convulsions continued to be manifested. The flesh of the two legs was then analyzed. The albumen was apparently scarcely affected, the mean of 6 experiments giving 2.10% of albumen in the electrified, and 2.13% in the non-electrified flesh. With regard to the extractive matters it appeared that in all the experiments, without a single ex-

¹ Müller's Archiv. 1845.

ception, the water-extract in the electrized flesh was diminished, while on the other hand the spirit- and alcohol-extracts were increased by that process. The results are expressed in the following tables.

Alcohol-extract from 100 parts of recent frog's flesh.

Exp.	a. In electrized portion.	b. In non-electrized portion.	a. : b.
1	0·753	0·606	1·24 : 1
2	0·569	0·427	1·33 : 1
3	0·664	0·481	1·38 : 1
4	0·652	0·493	1·32 : 1
5	0·575	0·433	1·33 : 1
Extracted with alcohol of 95 per cent.			
6	1·020	0·748	1·36 : 1
Water-extract.			
	a. b.	a. : b.	
7	1·21	1·63	0·79 : 1
8	0·93	1·23	0·76 : 1
9	0·72	0·90	0·80 : 1
Mean	0·95	1·25	0·78 : 1
Spirit-extract.			
	a. b.	a. : b.	
7	1·69	1·50	1·13 : 1
8	1·65	1·35	1·22 : 1
9	1·76	1·53	1·15 : 1
Mean	1·70	1·46	1·16 : 1

The amount of fat was unaffected. No urea could be found in the alcohol-extract.

There is great difficulty in performing experiments of this nature on warm-blooded animals, in consequence of the rapidity with which isolated portions of muscle lose their irritability.

The best results were obtained with decapitated pigeons.

	a. In electrized muscle.	b. In non-electrized muscle.	a. : b.
Albumen	-	2·04	2·13
Water-extract	-	0·64	0·73
Spirit-extract	-	1·68	1·58

It remains to be considered whether the fibrin takes part in this decomposition: *a priori* we should infer that it did, for the protein-compounds seem universally the conductors of the highest vital energies, and further the increased amount of sulphates and phosphates in the urine after muscular exertion indicates a decomposition of the sulphur and phosphorus compounds.

The above facts sufficiently show that muscular action is always accompanied by a chemical change in the composition of the acting muscle.]

The Brain, Spinal Cord, and Nerves.

Chemical analyses of the brain, spinal cord, and nerves are not calculated to throw much light on the functions of the nervous system in relation to the animal organism.

According to the analyses of Couerbe, the mass of the brain contains five different sorts of fat, viz. cholesterin, eleencephol, cerebrot, stearoconot, and cephalot.¹ Frémy, who has paid much attention to the subject, found albumen, cholesterin, two peculiar acids—cerebric and oleo-phosphoric acids, besides traces of olein, margarin, and their acids, in the brain. These acids are partly free and partly (especially the oleo-phosphoric) combined with soda.

¹ See p. 75.

These fatty matters are contained almost exclusively in the white or medullary substance; after their removal a substance remains, analogous to the gray matter. Frémy has also detected these peculiar acids in the spinal cord and nerves.

The quantity of water in the brain is very considerable, and amounts to about 80%: Frémy estimates it at 88%, the remaining 12% consisting of 7% of albuminous matter insoluble in alcohol, ether, and water, and 5% of the aforesaid fats, and their compounds.

Denis found in the brain of a man aged 20 years:

Water	-	-	-	-	-	78.0
Albumen	-	-	-	-	-	7.3
Phosphorized fat	-	-	-	-	-	12.4
Extractive matter and salts	-	-	-	-	-	1.4

In the brain of a man aged 78 years, he found:

Water	-	-	-	-	-	76.0
Albumen	-	-	-	-	-	7.8
Phosphorized fat	-	-	-	-	-	13.1
Extractive matter and salts	-	-	-	-	-	2.5

Vauquelin found in the human brain:

Water	-	-	-	-	-	70.00
Albumen	-	-	-	-	-	7.00
Fat	-	-	-	-	-	5.23
Phosphorus	-	-	-	-	-	1.50
Extractive matter	-	-	-	-	-	1.12
Acids, bases, and sulphur	-	-	-	-	-	5.15

Lassaigne has made the following analyses of the brain of an insane person:

	Cortical and medullary substance together.				Cortical substance.	Medullary substance.
Water	-	-	-	77.0	85.0	73.0
Albumen	-	-	-	9.6	7.5	9.9
Colourless fat	-	-	-	7.2	1.0	13.9
Red fat	-	-	-	3.1	3.7	0.9
Extractive matter, lactic acids, salts	-	-	-	2.0	1.4	1.0
Phosphate of lime, magnesia, and peroxide of iron	-	-	{	1.1	1.2	1.3

[The following table has been drawn up by L'Heretier¹ from his own researches. The numbers in each instance represent the mean of six analyses:

	Infants.	Youths.	Adults.	Aged persons.	Idiots.
Water	-	82.79	74.26	72.51	73.85
Albumen	-	7.00	10.20	9.40	8.65
Fat	-	3.45	5.30	6.10	4.32
Osmazome and salts	-	5.96	8.59	10.19	12.18
Phosphorus	-	0.80	1.65	1.80	1.00
					0.85]

According to Vauquelin, the medulla oblongata and the spinal cord contain the same constituents as the brain, but a larger proportion of fats and a less amount of albumen, extractive matter, and water.

[L'Heretier found that the spinal cord of an adult was composed of:

¹ Traité de Chim. pathol. p. 596.

Water	:	:	:	:	71.05
Albumen	:	:	:	:	7.30
Fat	:	:	:	:	8.25
Osmazome	:	:	:	:	11.50
Phosphorus	:	:	:	:	1.90

The nerves, according to the same chemist, contain more albumen, less solid and more soft fat than the brain.]

On boiling the nerves in alcohol a fluid fat exudes which sinks to the bottom of the vessel: on boiling them with water they swell but do not dissolve. The albumen of the medullary portion dissolves in a weak solution of potash, the fat swims on the surface, and the neurilema remains. On treating the nerves with acetic acid the medullary portion is expressed by the contraction of the tubes, which are themselves unacted on.

Fat.

The fat contained in the fat-cells is a mixture of margarin and olein in man and the carnivora, of stearin and olein in the ruminantia. Human fat usually occurs in a fluid or semifluid state, consisting of a solution of margarin in olein, from which the margarin separates on cooling into microscopic stellar groups.

The Glands.

Our knowledge of the chemistry of the glands is very defective, and in all probability the analysis of the organs will never throw much light on the process of secretion, in consequence of the utter impossibility of separating the nerves, vessels, and cellular substance. Fromherz and Gugert attempted to analyze human liver. They found in 100 parts:

Water	:	:	:	:	61.79
Solid residue	:	:	:	:	38.21

The insoluble parenchyma formed 28.72% and the portion soluble in water and alcohol 71.28% of the solid residue: 100 parts of dried liver contained 2.634 of salts, consisting of chloride of sodium, phosphate and a little carbonate of lime, phosphate of potash, and traces of peroxide of iron.

In the liver of the ox Braconnot found water 55.50, soluble matter 25.56, walls of vessels and membrane 18.94.

In certain morbid conditions of the system the liver becomes much affected. Its amount of fat is so extraordinarily increased in certain cases as to conceal the true structure; for the fat, as Rokitansky observes, not only occupies the place of the true glandular tissue, but all the tissues are permeated and the vascular substance perfectly overwhelmed. This morbid condition has been very frequently observed associated with pulmonary phthisis, and is a consequence of too luxurious a life, and the abuse of spirituous drinks. Fromherz and Gugert analyzed a liver of this nature. It weighed twelve pounds, and had a soft caseous appearance. Its true organization

appeared entirely destroyed. It contained a non-saponifiable fat with a small quantity of uncoagulated albumen, a little extractive matter, casein, salivary matter, a few shreds of vessels, chloride of sodium, and phosphate of lime: they found no cholesterol, fatty acids, or bilifellinic acid.

[A fatty liver analyzed by Frerich,¹ yielded:

Water	-	-	-	-	73.09
Solid constituents	-	-	-	-	26.91
Fat containing phosphorus	-	-	-	-	17.26
Albumen	-	-	-	-	3.67
Vessels and hepatic cells	-	-	-	-	4.00
Water-extract	-	-	-	-	0.48
Alcohol-extract	-	-	-	-	1.50

A waxy liver (a variety of the above) yielded;

Water	-	-	-	-	80.20
Solid constituents	-	-	-	-	19.80
Fat containing phosphorus, and cholesterol	-	-	-	-	2.20
Albumen	-	-	-	-	3.60
Vessels and hepatic cells	-	-	-	-	3.60
Water-extract	-	-	-	-	7.00
Alcohol-extract	-	-	-	-	4.50

The two following analyses have been made by Boudet:

	Fatty liver.	Healthy Liver.
Water	55.15	76.39
Solid constituents	44.85	23.61
Animal matter dried at 212°	13.32	21.00
Saponifiable fat	30.20	1.60
Cholesterol	1.33	0.17]

The thyroid gland has been analyzed by Fromherz and Gugert, and the thymus by Morin.

The kidneys have been submitted to analysis by Berzelius. From two experiments he concludes that the kidneys are made up of a congeries of minute vessels, and that the tubes contain a very albuminous acid fluid, in which there is no dissolved fibrin, and in which not a trace of urea can be detected.

[According to Boudet, the parenchyma of the lungs, freed as much as possible from blood and extraneous substances, is formed of the following chemical elements:—1st, a substance susceptible of transformation into gelatin by ebullition in water, (cellular tissue); 2d, a substance soluble in cold water, precipitated by nitric acid, coagulated by heat, containing albumen and haematin; 3d, a substance analogous to casein; 4th, fibrin; 5th, free oleic and margaric acids; 6th, oleate and margarate of soda; 7th, cerebric acid; 8th, lactic acid; 9th, cholesterol amounting to 0.5% of the weight of the lungs dried at 212°; 10th, the water amounting to 82%. The ash contained a considerable quantity of chloride of sodium and sulphate of soda, a small quantity of phosphate and carbonate of lime, and traces of silica and peroxide of iron.]

¹ Schmidt's Jahrbücher, vol. 48, p. 148.

Otolithes.

The membranous labyrinth of the ear contains a rather viscid fluid, which, however, never occurs in sufficient quantity to admit of chemical examination. In this fluid there are found minute six or eight-sided crystals (otolithes,) which, however, are generally so worn at the angles and borders that the crystalline form can be no longer recognised. They appear to consist for the most part of the carbonates of lime and magnesia combined with animal matters, and not unfrequently with phosphates.

CHAPTER XII.

SOLID MORBID PRODUCTS.

Concretions.

THESE morbid products are of frequent occurrence. They are found in various organs, especially in those through which fluid glandular secretions are discharged. They then consist for the most part of the most insoluble constituents of that fluid, although they occasionally contain substances foreign alike to the secretion and to the whole organism, and produced by a depraved formative process. Concretions are, however, also met with in other situations, as the brain, the cavities of the heart, the arteries, &c.

The substances ordinarily entering into the composition of concretions are by no means numerous. Some concretions are formed of one constituent alone, while others have a mixed composition. The following substances must be viewed as true formative constituents, not as mere accidental admixtures: uric acid with its salts, uric oxide (xanthic oxide,) cystin, hippurate of ammonia, basic and neutral phosphate of lime, ammoniaco-magnesian phosphate, oxalate of lime, carbonate of lime, carbonate of magnesia, fibrin, cholesterol, and biliphæin: the accidental components are mucus of the urinary and gall-bladders, albumen, hæmato-globulin, bilifellinic acid, fat, extractive matters, chloride of sodium, and lactate of soda.

The principal object in the analysis of concretions is to determine the nature of the leading constituents, and this may be easily effected even by persons little skilled in chemical manipulation. A blowpipe, a little platinum foil, and a few tests, comprise all the requisite apparatus.

Qualitative analysis of concretions.

On heating a little of the concretion on platinum foil with the blowpipe, three things may happen: the portion tested may entirely disappear, or a part may disappear, while the rest becomes whitened

by incineration, or finally, it may become blackened without, or with very slight diminution in size:

1. If the tested portion disappear entirely, it may consist of uric acid; urate of ammonia, or both, hippurate or benzoate of ammonia, uric oxide, cystin, cholesterin, biliphæn, fibrin, albumen, or hair.

a. It is uric acid if, when carbonized by exposure to heat on platinum foil, it gives off a peculiar animal odour resembling hydrocyanic acid, and diminishes to a scarcely visible residue; when a portion of the concretion heated with nitric acid dissolves therein with effervescence, and, after evaporation nearly to dryness, assumes, on the addition of ammonia, a beautiful purple tint; and when it dissolves thoroughly in a weak solution of caustic potash or its carbonate, and at the same time is insoluble in water, alcohol, and dilute hydrochloric acid.

b. It is urate of ammonia (which seldom occurs alone) if it behaves before the blowpipe, and with nitric acid, in just the same manner as uric acid, but at the same time, evolves an ammoniacal odour when heated on platinum foil, and develops a considerable amount of free ammonia on being triturated with caustic potash; and if it dissolves in boiling water.

c. It is uric or xanthic oxide if it burns without the peculiar odour of uric acid, if it dissolves without effervescence in hot nitric acid, and the evaporated solution when treated with ammonia assumes, not a rich purple, but a dark yellow colour; and if, finally, it is insoluble in a dilute solution of carbonate of potash.

d. It is cystin if it burns before the blowpipe with a blue flame, emitting at the same time, a pungent acid odour; if when treated with nitric acid it assumes (instead of a purple or yellow) a brown tint; if it dissolves in a dilute solution of carbonate of potash, and in caustic ammonia, and if it crystallizes from the latter in six-sided plates, easily recognised under the microscope.¹

e. It contains benzoate of ammonia if alcohol extracts a substance which, after evaporation is soluble in water, and if, on the addition of hydrochloric acid to the aqueous solution, crystals are separated, which dissolve readily in alcohol and evolve an odour of benzoic acid.

f. It is cholesterin if the concretion exhibits a crystalline character, if the portion under examination burns with a bright flame, if it dissolves in boiling alcohol, and separates from it on cooling in crystalline plates or scales, and if it does not dissolve in caustic potash.

g. Biliary resin is a frequent constituent of biliary calculi, but never occurs alone. It may be easily recognised by its solubility

¹ [In order to detect the presence of cystin, a portion of the suspected calculus should be dissolved in a strong solution of caustic potash, and a solution of acetate of lead added in excess; the liquid must then be heated to the boiling point. If cystin be present, insoluble sulphuret of lead is formed, which at first gives the liquid the aspect of ink, but is shortly precipitated, while oxalate of ammonia remains in solution.]

in alcohol, by its extremely bitter taste, and by its separation from its alcoholic solution on the cautious addition of water.

h. It is biliphæin if it has a brown or ochre-yellow colour, if it evolves an animal odour on burning, if it is only slightly soluble in alcohol and water, but freely in caustic potash, communicating to it a dark brown tint, and if the addition of nitric acid to this solution causes the well known change of colour.

i. It is fibrin if it softens when heated on platinum foil and evolves an odour of burnt horn, burning with a clear flame, and leaving scarcely any residue; if it dissolves in caustic potash from which it is precipitable by acetic acid, and finally, if it dissolves in an excess of acetic acid from which it is precipitable by ferrocyanide of potassium. It must be remembered that this description applies equally to albumen.

k. Concretions containing hair may be known by their light specific gravity, and by their appearance on making a section. When burned they develop an odour of burned horn. They dissolve in caustic potash, but in none of the other ordinary solvents.

2. If the portion submitted to examination becomes black on the first application of heat, and only slightly diminishes, it may consist of the earthy phosphates, carbonates, and oxalates, or of the urates with fixed bases, for then the uric acid becomes converted by heat into carbonic acid, and the bulk of the specimen does not very perceptibly diminish.

a. It is neutral phosphate of lime (which is not often the sole constituent) if, when the heat is continued, it fuses, and neither before nor afterwards effervesces with acids; if it dissolves readily in hydrochloric acid, from which it is precipitable as an amorphous powder by ammonia; and if, after the ammonia ceases to cause any further deposit, the filtered solution yields a precipitate to oxalate of ammonia.

b. It is basic phosphate of lime (which never occurs alone, but is often associated with the salt which will be next considered) if it easily burns white but does not fuse, even under the continued action of the blowpipe. It fuses, however, when combined with the following salt (*c.*) and its fusibility is proportionate to the amount of the magnesian salt present: consequently such a compound may be mistaken for the neutral phosphate of lime. If it fuses before the blowpipe, and a solution in dilute hydrochloric acid yields a precipitate with ammonia, which, under the microscope, appears in the crystalline form represented in fig. 25; or if after the hydrochloric-acid solution has been saturated with ammonia, and all the lime thrown down by oxalate of ammonia the filtered solution again yields a precipitate to caustic ammonia; then it is not neutral phosphate of lime, but the basic phosphate, in combination with the following salt. With the exception of the blowpipe test, the chemical characters of these two compounds are similar.

c. It is ammoniaco-magnesian phosphate (which usually occurs in

calculi associated with one of the preceding compounds) if it develops a disagreeable ammoniacal odour before the blowpipe, and then fuses; if it dissolves, without effervescence, in hydrochloric and acetic acids, and, after the solution has been nearly saturated with ammonia, is not affected by oxalic acid, but is precipitated in the beautiful crystalline form represented in fig. 25, by an excess of free ammonia.

In proportion to the amount of basic phosphate of lime, mixed with the ammoniacal-magnesian phosphate, the less readily it fuses.

d. It is oxalate of lime if it does not fuse before the blowpipe, if it easily burns white, and distributes a brilliant light; if the heated specimen, when moistened with water, does not dissolve, but exhibits a strong alkaline reaction, and dissolves with effervescence in hydrochloric acid (or, if the heat has been long continued and very intense, without effervescence;) and if, after the solution has been neutralized by ammonia, oxalate of ammonia throws down a precipitate.

If the specimen is not affected by acetic acid, but dissolves readily in nitric or hydrochloric acid without effervescence, and is precipitated therefrom by ammonia; and if, farther, the nitric-acid solution evaporated nearly to dryness and treated with ammonia develops no purple tint, it consists of oxalate of lime.

e. It is carbonate of lime if it easily burns white before the blowpipe, and in other points resembles oxalate of lime after exposure to a red heat; if the fresh specimen dissolves with effervescence in acetic or hydrochloric acid, and the solution is not precipitated by ammonia; and if oxalate of ammonia throws down a precipitate from the ammoniacal solution.

f. It is urate of soda (which never occurs alone in urinary concretions, but is found, like the urate of potash, in small quantity in calculi of uric acid and the earthy phosphates,) if it fuses readily before the blowpipe, but burns white with difficulty, and communicates an intense yellow tint to the flame; if the residue (with the exception of particles of carbon) dissolves easily in water, to which it communicates an alkaline reaction, and dissolves with effervescence in hydrochloric acid, if the addition of bichloride of platinum to the filtered solution mixed with alcohol, produces no deposit; and if a fresh specimen dissolves in water on the application of heat, dissolves in nitric acid without effervescence, and the solution, after evaporation nearly to dryness, assumes a purple tint on the addition of ammonia.

g. It is urate of potash if it behaves exactly like urate of soda, (with the exception of communicating a yellow colour to the flame of the blowpipe;) and if a yellow precipitate is formed on the addition of bichloride of platinum to an alcoholic solution of the ash dissolved in hydrochloric acid. If, in conjunction with the occurrence of the yellow precipitate, the specimen communicates an intense yellow colour to the flame of the blowpipe, urate of soda is mixed with the urate of potash.

h. It is urate of lime (which never occurs alone, but is usually associated with uric acid in calculi) if it burns white but does not fuse before the blowpipe, and then acts in the manner described in (*e*); and if a small portion of the fresh specimen dissolved in boiling water affords the ordinary evidence of uric acid when treated with nitric acid and ammonia. If the assay slightly fuses and runs together, and is then partially soluble in water, urate of soda or potash is mixed with the urate of lime; the solution has a strong alkaline reaction, and effervesces on the addition of an acid.

i. It is urate of magnesia (which occurs very rarely in calculi, and then only with uric acid) if it readily burns white before the blowpipe, but does not fuse; and if the residue is insoluble in water, but soluble without (or with very slight) effervescence in dilute sulphuric acid; and if caustic potash throws down a precipitate from this solution.

k. It contains silica (a rare constituent) if, after prolonged exposure to heat, and digestion of the residue in hot hydrochloric acid, an insoluble residue remains, which becomes white before the blowpipe, and fuses into a clear bead when mixed with carbonate of potash or soda.

3. The specimen may be partially consumed on exposure to heat, while the residue undergoes no further change under the action of the blowpipe. Concretions of this sort are by no means rare; they consist of a mixture of the compounds of the 1st and 2d classes. Indeed, calculi, composed merely of one of the substances already enumerated, are very rare, for although in one class of calculi, uric acid may be the preponderating constituent, in another oxalate of lime, and in a third the earthy phosphates, we almost always find associated with these substances a certain amount of other matters; for instance, uric acid and the urates are of frequent occurrence in calculi chiefly composed of oxalate of lime or of the earthy phosphates.

Intestinal concretions consist for the most part of earthy phosphates with a little fat, extractive matters, and vegetable fibre; biliary concretions, of cholesterol mixed with a little bile-pigment and biliary resin, or of bile-pigment and biliary resin with a little cholesterol. Other classes of concretions (with the exception of arthritic concretions, which consist for the most part of urate of soda) are composed of earthy phosphates and carbonates combined with organic (albuminous, extractive, and fatty) matters.

In the analysis of mixed concretions we proceed in the following manner:

A. We incinerate a portion in a platinum crucible, and analyze the residue; if it burns white easily, the infusible earths preponderate; if it is difficult or impossible to obtain a white residue, and the ash remains fused and blackish, then the fusible earths or the alkalies preponderate. The residue may consist either of (1) earthy phosphates alone, which may be recognised by the rules given in 2, *a*, *b*, and *c*, or of (2) earthy phosphates and carbonates, the latter originating from

earthy urates, or oxalate of lime. (In this case we recognise the presence of earthy carbonates (or of caustic earths, if the heat has been too intense and prolonged,) by the rules laid down in 2, d, e, and h.)

4. The residue may consist of earthy phosphates and carbonates, and alkaline carbonates, if alkaline urates occur in the concretion. In order to detect the alkaline carbonates the residue must be pulverized and extracted with water; on the evaporation of the decanted water the alkaline carbonates will remain, and may be recognised by the rules given in 2, f, and g. The portion insoluble in water is readily dissolved in dilute hydrochloric acid, usually with a slight effervescence.

Ammonia precipitates the earthy phosphates from this solution; after filtration oxalate of ammonia throws down the lime, and after a second filtration phosphoric acid and ammonia cause a precipitation of the magnesia.

5. Silica may be easily recognised by the rule given in 2, k.

B. The portion consumed and expelled by exposure to heat, consists of uric acid, of urate of ammonia, of the oxalic acid of oxalate of lime, which is converted into carbonic acid, of the carbonic acid of carbonate of lime, which is expelled at a high and prolonged temperature, of cystin, of ammonia yielded by ammoniaco-magnesian phosphate, of cholesterin or other fats, of bile-pigment, bilin, extractive matters, or other animal or vegetable substances mechanically entangled, as mucus, albumen, or vegetable fibre.

We may convince ourselves of the presence of uric acid by observing the action of nitric acid and ammonia on a portion of the specimen, and its salts may be demonstrated by extraction with boiling water, and the addition of nitric acid to the nearly dried residue.

The presence of oxalic acid may be shown by the digestion of the same portion in hydrochloric acid (the urates having been previously extracted by water;) on the addition of ammonia, oxalate of lime is precipitated, which, after heating, dissolves with effervescence in the same acid. The presence of carbonic acid in the specimen may be shown by the effervescence produced on the immersion of a fragment in hydrochloric acid; the presence of ammonia dependent on the ammoniaco-magnesian phosphate, by its development on triturating a portion with caustic potash, the urate of ammonia having been previously removed by boiling water; the presence of cystin, by digesting the specimen in caustic ammonia, and observing the six-sided plates in which it crystallizes on the spontaneous evaporation of the ammonia; the presence of cholesterin (in human biliary calculi,) of biliphaein (in the biliary calculi of cattle,) of hair, and of vegetable fibre, may be determined after some practice by the internal structure and the colour of the concretion.

In this simple manner we may arrive at a knowledge of the qualitative composition of a calculus; the analysis is, however, in some respects facilitated by a knowledge of its origin. We know, for in-

stance, that uric acid and its salts occur only in renal, vesical, and arthritic concretions; that the earthy phosphates occur equally in intestinal and vesical calculi; and that carbonate of lime is a common constituent of concretions in the brain, nose, and salivary glands; while, on the other hand, oxalate of lime is almost exclusively found in renal and vesical calculi, and cholesterin, bile-pigment, and biliary resin only in gall-stones.

On vesical and renal calculi in man.

The concretions of most importance in relation to practical medicine, are vesical and renal calculi and gravel. The constituents of urinary calculi, according to the statements of different observers, are, 1, uric acid; 2, urate of ammonia; 3, urate of soda; 4, urate of magnesia; 5, urate of lime; 6, benzoate or hippurate of ammonia; 7, oxalate of lime; 8, oxalate of ammonia; 9, uric or xanthic oxide; 10, cystin; 11, neutral and basic phosphate of lime; 12, ammoniaco-magnesian phosphate; 13, carbonate of lime; 14, carbonate of magnesia; 15, fibrin; 16, silica.¹ Mixed with these constituents we likewise meet with fat, extractive matters, albumen, vesical mucus, and peroxide of iron.

Of these constituents those numbered 1, 2, 7, 11, 12, are the most common, and occur in the largest quantity; those numbered 3, 4, 5, 13, 14, 16, are not of rare occurrence, but are usually met with in very small quantity in calculi composed of other ingredients. Uric oxide (9) has been only observed in three [four] cases; and cystin is by no means common.

Fibrin was once noticed by Maracet as a constituent of a urinary calculus, but Berzelius is inclined to suppose that in reality it was vesical mucus.

The presence of benzoate or hippurate of ammonia in urinary calculi, recorded by Brugnatelli, and of oxalate of ammonia, described by Devergie, is scarcely compatible with the great solubility of these salts.

The following points respecting the physical character of urinary calculi are deserving of notice:

The form varies in accordance with the seat of origin and the chemical composition; the oval or spheroidal is the most frequent: round calculi are often compressed laterally, and renal concretions sometimes assume a polygonal or even a branching coralline form; in the ureters cylindrical calculi with prominences and depressions have been described. The surface is smooth, and presents few irregularities in calculi of uric acid; it is flat and more or less rough in many phosphatic calculi; earthy and easily triturable in urate of ammonia calculi; tuberculated, as we sometimes observe in calculi of uric acid, the urates or cystin; or armed with prominences and asperities in the oxalate of lime calculi.

¹ [To these Heller has recently added urostolith.]

The colour of these concretions varies for the most part from a pale yellow to a yellowish-red, brown, or brownish-green.

Calculi of the earthy phosphates are colourless, or nearly so; calculi of uric acid and the urates vary from a yellow to a reddish-yellow or brown; calculi of oxalate of lime are yellow, yellowish-brown, brownish-green, or blackish-green. Calculi of uric oxide are of a cinnamon-yellow colour, and those of cystin of a yellow tint. In size and weight they present, as might be supposed, the greatest variety; their specific gravity varies from 1.213 to 1.975. Calculi of oxalate of lime exhibit the greatest density, those which consist of the earthy phosphates, and especially of ammoniaco-magnesian phosphate, are the lightest.

With respect to absolute weight, urinary concretions may vary from one or two grains (when they merely form gravel) to several ounces. Some cases of enormous and almost incredible size are related; Morand describes a stone in his possession weighing 6 pounds and 3 ounces, Lister describes a stone of 51, and Earle one of 44 ounces; the latter was 16 inches in circumference. With regard to the number of calculi that may occur in the same person, we may mention that Murat found 678 in the bladder of an old man, and nearly 10,000 in his kidneys. Buffon's bladder contained 59 calculi. When several calculi exist in the bladder their form becomes modified, and they are usually more or less flattened by mutual apposition and friction. I am in possession of a calculus consisting of two portions; the upper is small, weighing about two ounces, triangular, and provided with three equal convex facettes, exactly fitting into the depression of the larger inferior part, which is of an oval form and weighs about five ounces. There can be no doubt that this peculiarity of form arose from the frequent rotation of the calculi.

The internal structure of urinary calculi is of importance; a section may exhibit either a uniform texture throughout, or concentric strata arranged around a nucleus. If the calculus is formed of a single ingredient, its fractured or cut surface appears coarse and finely granular, and sometimes presents a radiating appearance, especially in uric-acid calculi: it is earthy and fragile, and does not present any regular arrangement in calculi of urate of ammonia: it is dense and conchoidal in oxalate of lime, and crystalline in cystin. Calculi of phosphate of lime, on the other hand, exhibit an almost fibrous structure, distinguished by parallel striæ. Calculi in which ammoniaco-magnesian phosphate is the predominating ingredient exhibit a porous internal surface, studded here and there with crystals.

In calculi consisting of a nucleus and of laminæ deposited round it, it is important to ascertain whether the nucleus and the concentric laminæ are identical or different in their composition.

The nucleus may consist either of one of the ordinary constituents of urinary concretions, or of a foreign body introduced into the bladder, as for instance, a fragment of wood, a grain of corn,¹ &c. The la-

¹ [Professor Malago has recently extracted a calculus, of which the nucleus was a globule of tarry. *Filiatre Sebezio, 1845.*]

mineæ may have the same chemical constitution as the nucleus, and only differ from it in the period of their deposition, as is the case with calculi of uric acid, urate of ammonia, uric oxide, and earthy phosphates: or they may differ from the nucleus in their composition; in this case we may always infer that changes have taken place in the character of the urinary secretion; for instance, if the nucleus consist of uric acid, and is surrounded by a concentric layer of the earthy phosphates, the urine must have been first constantly acid, and subsequently neutral or alkaline.

I now proceed to the consideration of the most common urinary calculi.

Combustible calculi.

I. *Calculi of uric acid* are by no means rare; their character have been already described in page 620; they may be distinguished from calculi of urate of ammonia by the solubility of the latter, and the insolubility of the former in a sufficient quantity of boiling water. They are of every possible size, their colour is sometimes (but very rarely) white, most commonly yellow, rose-coloured, or brown; their surface is smooth, sometimes even polished, and occasionally presents rounded verrucose protuberances. Their fractured surface presents either a crystalline appearance, or is dense with concentric strata merging into each other. The nucleus is crystalline, and the surrounding laminae hard. I have found a minute grain of urinary gravel in the centre of several calculi of uric acid, and the central portions are often darker coloured than the peripheral. The uric acid in these calculi is never pure, but is always mixed with colouring matter—the uroerythrin (which always accompanies uric acid)—frequently with alkaline urates, and occasionally with small quantities of earthy phosphates. A very minute quantity of fat and of extractive matter occurs in this as well as in most other sorts of urinary calculi.

In order to obtain an accurate knowledge of the composition of a calculus, it must be sawed through the centre, and the different strata submitted to distinct analyses if they present any variation in their physical characters: it does not often happen that a calculus which consists externally of uric acid is composed in its interior of earthy phosphates, oxalate of lime or cystin, but on the other hand uric acid often forms a nucleus to calculi formed of other constituents. In order to determine whether fixed alkaline urates, or earthy phosphates are contained in a calculus, a portion must be incinerated and the residue analyzed. If they are present they may be determined by the rules given in 2, a, b, c, f, g, h, and 3.

A portion of each lamina, or if the calculus is uniform throughout, some of the dust separated in the operation of sawing, is reduced to an impalpable powder; a weighed quantity is placed in a small porcelain basin, and after being warmed for some time on the water-bath, is placed under the exsiccator in order to remove every trace of

moisture. A known portion of the dried powder is placed in a small glass flask, and repeatedly extracted with ether, whereby the fat is removed; and the residue is boiled with alcohol of specific gravity .850, which takes up some extractive matter. The powder is then boiled with distilled water till nothing further can be removed by that menstruum. On evaporating the watery solution in a small porcelain capsule we obtain the urates as a residue. If it is requisite that this part of the analysis should be carried further, we dry the residue and weigh it; we then heat it in a little water and add hydrochloric acid; the uric acid separates, and the bases combine with the hydrochloric acid. The uric acid is collected on a filter, washed with water, dried, and weighed; the hydrochloric-acid solution is evaporated, and yields a residue of hydrochlorate of ammonia, and probably the chlorides of sodium and calcium. In order to separate these substances the dried residue is first weighed, and then dissolved in water; some ammonia, and subsequently oxalate of ammonia are added, in order to precipitate the lime. The fluid after filtration is evaporated, and the dried residue exposed to a strong heat: the chloride of sodium is left, and the chloride of ammonium may be estimated by the loss of weight. The bases are calculated from the lime which is left after the exposure of the carbonate of lime to heat, and from the chlorides of sodium and ammonium, and are combined with the uric acid.

The portion of the powdered calculus not taken up by water is treated with dilute hydrochloric acid, which dissolves any earthy phosphates that may happen to be present. They are precipitated by the addition of ammonia to the acid solution, and must be then collected on a filter, washed, dried, and weighed. The uric acid (the remaining constituent) must be perfectly dissolved in caustic potash, from which it must be precipitated by super-saturation with hydrochloric acid. It must be then washed on a filter, dried, and weighed. The acid solution usually contains a trace of organic matter, (vesical mucus or albumen;) its presence may be detected by the addition of a little ferrocyanide of potassium, which causes a precipitate.

II. *Calculi of urate of ammonia.* This form of calculus is somewhat rare, and indeed its existence was regarded as uncertain till Prout determined the point beyond a doubt. According to Fourcroy these calculi are usually small, occur more frequently in children than in adults, have a whitish or clay-colour, a smooth or tuberculated surface, and an earthy fracture exhibiting concentric strata. Yellowly found that of 59 small stones taken from a man aged 45 years, 24 consisted of urate of ammonia and 35 of uric acid. Urate of ammonia occurs, however, most frequently mixed with other constituents, especially with uric acid: moreover it often forms the nucleus of large calculi, or occurs as a stratum between a nucleus of uric acid and an external coating of phosphates; in such cases, however, it is not pure but mixed with crystals of uric acid, or oxalate or

phosphate of lime. Urate of ammonia acts before the blow-pipe in just the same manner as uric acid, and their reactions with nitric acid are also similar: they may, however, be readily distinguished by the comparative solubility of the former in boiling water, and by the evolution of ammonia that takes place on triturating it with caustic potash. In a careful examination of a calculus of urate of ammonia, the first point is to ascertain if other constituents are present which is usually found to be the case. If there is a residue left after heating it before the blow-pipe, that residue may consist of earthy phosphates, or earthy or alkaline carbonates: the alkaline carbonates correspond with the alkaline urates, the carbonate of lime with the oxalate of lime. In this case the calculus must be reduced to a very fine powder and dried; a weighed portion must then be freed from fat and extractive matter by ether and alcohol, and afterwards repeatedly boiled in small quantities of distilled water, till the water is no longer affected. When the calculus is finely powdered the urate of ammonia dissolves with tolerable facility in boiling water. The earthy phosphates and the oxalate of lime must be extracted with dilute hydrochloric acid,¹ precipitated by ammonia, dried, weighed, and exposed to a high temperature. If we again dissolve this residue in hydrochloric acid, and throw down the earthy phosphates with ammonia, chloride of calcium remains in solution, arising from the oxalate of lime. Whatever remains unacted on by dilute hydrochloric acid is uric acid.

The urates of soda and potash, as well as the urate of lime are (as I have already mentioned) often found in calculi of uric acid; they likewise occur in calculi of urate of ammonia. All these urates are soluble in boiling water; their mode of separation has been already described. If urate of magnesia should also be present (which is probably seldom the case,) a different method of separation must be adopted. Hydrochloric acid is added to the evaporated aqueous solution in order to precipitate the uric acid; the acid solution, after filtration, is evaporated on the water-bath, and we then obtain a residue of mixed chlorides. The dried residue, after being weighed, is moistened with a little concentrated hydrochloric acid, and afterwards treated with anhydrous alcohol, which takes up the chloride of magnesium. The alcoholic solution is treated with a little carbonate of potash, evaporated, and dried in a platinum crucible heated to incipient redness. After the extraction of the potash, the magnesia remains. The chlorides of calcium, sodium, and ammonium, must be separated in the ordinary manner.

III. *Calculi of uric (xanthic) oxide.* Calculi of this substance usually contain no other constituent, with the exception of a little animal matter. Uric oxide was first met with by Marcell, forming a calculus weighing 8 grains; some years afterwards a few minute concretions of the same nature were described by Laugier: more recently it was discovered by Stromeyer in a calculus weighing 338

¹ [Unless the hydrochloric acid is tolerably strong, it will not dissolve the oxalate of lime.]

grains, and as large as a pigeon's egg, extracted by Langenbeck; [and a fourth specimen weighing 7 grains, has been lately described by Dulk.¹] Their external surface is smooth and polished, and of a cinnamon-brown colour. Their cut surface is of a brown flesh-colour, and consists of concentric laminæ easily separable from each other. In point of hardness they resemble uric acid, and when rubbed they assume a waxy appearance. Although uric oxide is of rare occurrence, it need never escape detection with ordinary care. The fact of its entire destruction before the flame of the blow-pipe at once distinguishes it from the calculi which contain fixed constituents; by its behaviour with nitric acid, and with carbonate of potash (in which uric acid dissolves, but uric oxide is insoluble,) it may be distinguished from uric acid, which it resembles in many respects.

In order to make a full analysis of a calculus of this description, it must be first pulverized, and then every thing soluble in ether, alcohol, and water removed. If uric acid is associated with it, carbonate of potash serves to separate the acid from the oxide; if earthy phosphates or oxalate of lime are present, they must be removed by dilute hydrochloric acid. Any urates that are present are taken up by water.

IV. Calculi of cystin. Calculi of cystin, although rare, are more common than those of uric oxide. Although sometimes mixed with other constituents, cystin most commonly forms the sole ingredient. These calculi seldom attain any great size; they are usually small, round, smooth, and of a yellow colour. In consistence such a calculus is soft; the cut surface presents a semi-transparent, confusedly crystalline appearance; not however laminated. When broken, it appears to be made up of small crystals of a waxy lustre, the margins of which are rounded. The microscope affords the best means of recognising the existence of cystin: if we dissolve a fragment in caustic ammonia, and allow it to evaporate spontaneously, crystals are deposited in six-sided tables or prisms. The peculiar behaviour of cystin before the blowpipe distinguishes it not only from calculi with fixed ingredients, but also from those of uric acid and uric oxide. It is also distinguished from the latter (with which, however, it has never yet been found associated) by its solubility in carbonate of potash, and in dilute hydrochloric acid; and from the former by its solubility in dilute hydrochloric, phosphoric and even oxalic acid. When cystin is associated in calculi with other constituents, it is most commonly found to alternate with uric acid. Thus Henry found a nucleus of cystin, and an external layer of cystin and a nucleus of uric acid. It is worthy of remark that Bley, in examining two calculi taken from the same man, found in one, cystin associated with carbonate of magnesia and ammoniaco-magnesian phosphate; in the other the cystin was displaced by uric acid. The calculus that contained the cystin was reniform, compressed, and flattened; of a yel-

¹ [Simon's Beiträge, p. 413: moreover Unger has discovered minute traces of a substance closely allied to uric oxide, if not identical with it, in guano.]

low colour and weighed 1·75 grains. It exhibited a stratified appearance internally, and when exposed to heat left scarcely a trace of ash. After the removal of the earthy matters by hydrochloric acid, there remained a residue soluble in potash, which, on the addition of acetic acid and evaporation, deposited small six-sided crystals.¹

It need scarcely be mentioned that if in a calculus containing cystin there is any perceptible difference between the nucleus and the surrounding strata, they must be analyzed separately.

V. *Calculi formed of protein-compounds. Fibrinous calculi*, according to Marcket.

All urinary calculi contain an organic matter, which, by prolonged digestion is soluble in acetic and in dilute hydrochloric acid, from which solutions it may be precipitated by ferrocyanide of potassium. It is readily soluble in caustic potash, but is insoluble in water, alcohol, or ether: it consists in most cases of the mucus of the bladder, occasionally of albumen. Marcket described a remarkable calculus consisting entirely of protein-compounds, and regarded by him as composed of fibrin. It had the appearance and consistence of yellow wax; its surface was irregular, but not rough; internally it exhibited a fibrinous character, and was, to a certain degree, elastic. When burned it evolved an odour of burning horn, and left a porous carbonaceous residue. It was insoluble in alcohol, ether, or water, but dissolved in caustic potash, from which it was precipitated by hydrochloric acid. It dissolved slowly in nitric acid, and when boiled in acetic acid, swelling previously to dissolving. It was precipitated from its acetic acid solution by ferrocyanide of potassium. In its solubility in nitric acid it does not (as Berzelius remarks) correspond very well with the properties of fibrin; its characters, as given by Marcket, lead more to the supposition that it was vesical mucus. Morrin has likewise described a calculus remarkable for the quantity of organic protein-like substance contained in it. It was associated with phosphate of lime, and amounted in the nucleus to only 10 $\frac{1}{2}$ %, in the second layer to 18 $\frac{1}{2}$ %, and in the third to 70% of the weight of the calculus. Alcohol took up a little fat. The substance was slightly soluble in acetic, more so in nitric acid: in caustic potash it swelled, became viscid, and partially dissolved.

Incombustible or partially combustible Calculi.

VI. *Calculi of oxalate of lime* are next in frequency to those of uric acid and the earthy phosphates. Their form is very characteristic; they are usually spherical, but their whole surface is studded by verrucose, tuberculated elevations, or even by sharp angular projections. It is from the former and most common of these appearances that they have received the name of mulberry calculi.

The size of these calculi varies from that of a hempseed to a

¹ It seems strange that the cystin did not dissolve in the hydrochloric acid. The case is recorded in Buchner's Report, 2d series, vol. 2, p. 165.

pigeon's egg, and is occasionally even larger. Thus out of thirty-three calculi of pure oxalate of lime examined by Smith there was only one that weighed an ounce and a half. Their colour varies; they are white, bright yellow, yellowish-brown, and occasionally dark green. The largest are usually the most darkly coloured. The fracture is usually firm, hard, finely-granular and conchoidal; but calculi have been observed by Berzelius which consisted of an aggregate of closely connected sharp angular crystals. Their specific gravity is higher than that of any other calculi. Hence it is evident that the physical characters alone are sufficient to prevent a calculus of this nature from being mistaken for one consisting of uric acid or of the earthy phosphates. The chemical characters are, however, equally distinct. It is distinguished from uric acid by its readily burning white before the blowpipe: it is distinguished from the earthy phosphates by its moistened residue exhibiting an alkaline reaction towards red litmus paper, and, if the heat has not been too intense, by its dissolving in hydrochloric acid with effervescence, by ammonia added to saturation producing no precipitate in this solution, but by a deposit being at once observed on the subsequent addition of oxalate of ammonia: it is distinguished from carbonate of lime by its dissolving in hydrochloric acid without effervescence, and by the solution being precipitated by ammonia: and, finally, it is distinguished from urate of lime by its insolubility in boiling water. Although oxalate of lime mixed with a little organic matter (mucus and colouring matter) is generally the sole constituent of mulberry calculi,¹ it is sometimes associated with uric acid, urate of ammonia, or phosphate or carbonate of lime. After what has been already stated, the separation of these substances can scarcely be considered difficult. Ether and alcohol remove fat and extractive matter, water removes the urates, hydrochloric acid the earthy phosphates and oxalate of lime: there can then remain nothing but uric acid with vesical mucus or coagulated albumen, and possibly a little silica. The hydrochloric-acid solution is supersaturated with ammonia, and the precipitate washed with a weak ammoniacal solution. It is exposed to a red heat, and dissolved in hydrochloric acid; the earthy phosphates are then precipitated by ammonia, and the lime separated from the filtered solution by oxalate of ammonia. In order to analyze the residue insoluble in hydrochloric acid, it must be boiled in caustic potash and filtered; the uric acid and silica must be thrown down by an excess of hydrochloric acid; if the precipitate is washed, weighed, and submitted to a red heat, we obtain the silica as a residue.

The amount of animal matter, and especially of pigment, is generally larger in these than in any other calculi. The animal matter seems to consist partly of protein-compounds, and partly of extractive matter. Whether the colouring matter is due to the haematin of the blood, or to uroerythrin, has never been determined.

¹ [Our own experience is opposed to this statement.]

VII. *Calculi of ammoniaco-magnesian phosphate and phosphate of lime.* These calculi are of the most common occurrence next to those of uric acid. They sometimes attain a very large size; they are usually globular or spheroidal; their colour is white, gray, or dull yellow; their fractured surface is less earthy than in the preceding calculi, and is interspersed with sparkling crystals; and although in general friable, their texture is occasionally compact and dense. When laminated, which is seldom the case, the intervals between the layers contain glistening crystals of ammoniaco-magnesian phosphate. On heating a fragment of a calculus of this nature on platinum foil an odour of ammonia is developed: it does not burn white so readily as the oxalate of lime, since the ammoniaco-magnesian phosphate, if present in any quantity, fuses and produces a grayish white enamel.

The moistened ash does not affect red litmus paper; it dissolves in hydrochloric acid without effervescence, and may be precipitated from it by ammonia. As these calculi contain a little fat and extractive matter, it is requisite in making a careful analysis that, after being pulverized, they should be extracted with ether and alcohol; on dissolving the residue in hydrochloric acid a small amount of flocculent matter is usually observed, arising probably from vesical mucus. The earthy phosphates are precipitated from this acid solution by ammonia, and after being washed are exposed to a red heat. Calculi of phosphates of lime and ammoniaco-magnesian phosphate often contain uric acid, the alkaline urates, and sometimes oxalate and carbonate of lime. The alkaline urates are, in that case, extracted with boiling water; on digesting a portion of the residue in dilute hydrochloric acid, the earthy phosphates are dissolved and the uric acid remains; if carbonate of lime is present, effervescence is observed on treating a little of the powdered calculus with hydrochloric acid; the lime may be precipitated by oxalate of ammonia, after the earthy phosphates have been thrown down from the acid solution by caustic ammonia. If oxalate of lime is present, the powdered calculus (the urates having been previously removed) after a short exposure to heat (but not before) effervesces on the addition of hydrochloric acid. The large calculus noticed in page 626 consists principally of earthy phosphates with small quantities of the urates of ammonia and soda lying one above the other in laminæ. It contains a nucleus about the size of a nut, of a mulberry appearance, consisting of oxalate of lime, and in the centre of this is a nucleolus of the size of a large pea, consisting almost entirely of uric acid.

VIII. *Calculi of neutral phosphate of lime* are very rare: they were first described by Wollaston. Their surface is usually pale brown, and so smooth as to appear polished. On sawing through a calculus of this nature it is found very regularly laminated, and the laminæ in general adhere so slightly to each other as to separate with ease into concentric crusts. Each lamina is striated in a direction perpendicular to the surface, as from an assemblage of fibres.

In these as in all other calculi we meet with a certain amount of animal matter, supposed by Berzelius to be identical with that which is associated with phosphate of lime when we precipitate that salt from the urine. Hence on heating a portion before the blowpipe it becomes charred, and evolves an odour of burned horn; it finally burns white and fuses, which distinguishes it from the basic phosphate of lime, which is infusible before the blowpipe. Since, however, ammoniaco-magnesian phosphate readily fuses before the blowpipe we must examine previously that none of it is present.

Basic phosphate of lime or bone-earth never occurs as the sole constituent of a urinary calculus; the same is the case with ammoniaco-magnesian phosphate.¹

IX. *Calculi of carbonate of lime.* Calculi consisting merely of carbonate of lime and animal matter, are somewhat rare. Smith found 18 such calculi in the bladder of a young man, and Brugnatelli mentions 48 pisiform concretions of the same nature taken from a young man, and 16, the size of a nut, from a woman. According to Berzelius they are generally white or gray, but sometimes yellow, brown, or red; the tint depending on the animal matter. The formation of these calculi is due to an alkaline condition of the urine, and to the absence of the ordinary phosphates. On heating a fragment before the blowpipe, it evolves an odour of burned bone, and readily burns white. On treating the residue with hydrochloric acid effervescence is observed, unless the heat has been very intense and prolonged, in which case the carbonate is converted into caustic lime, and it dissolves without effervescence: in this case it is also soluble in water and forms an alkaline solution. If a fragment of the unheated calculus is pulverized and treated with dilute hydrochloric acid, it dissolves with effervescence and leaves a residue of vesical mucus.

Although it seldom occurs as the principal ingredient, it is often found associated with other constituents, especially with phosphate of lime, in urinary calculi.

I have examined two yellow calculi of the form and size of a pea, taken from the kidney; they consisted of carbonate and phosphate of lime. Proust also mentions vesical calculi composed of carbonate and phosphate of lime. Proust was the first who detected carbonate of lime in urinary calculi: it was in that instance associated with phosphate of lime and traces of urate of lime. Walther describes six calculi in which the nucleus was urate of ammonia, while the cortex was composed of carbonate and phosphate of lime. Proust mentions a mulberry calculus in which the external layer was soft, and consisted of oxalate and carbonate of lime, the second of carbonate and phosphate of lime, and the third of phosphate of lime. Brugnatelli states that he examined a urinary secretion consisting of carbonate and oxalate of lime, and benzoate of ammonia.

¹ [A human calculus composed entirely of ammoniaco-magnesian phosphate is described by Scharling, 'On the Chemical Discrimination of Vesical Calculi,' translated by Dr. Hoskins, p. 55.]

When carbonate and oxalate of lime occur together, the calculus dissolves in hydrochloric acid with effervescence, both before and after heating. Before the application of heat it is partially soluble in acetic acid with effervescence, the oxalate remaining undissolved.

On dissolving a portion of the calculus in dilute hydrochloric acid, and adding ammonia, we precipitate the oxalate of lime; the lime corresponding to the carbonate may then be precipitated from the filtered solution by oxalate of ammonia. The oxalate of lime precipitated by ammonia may be easily mistaken for phosphate of lime; all ambiguity may, however, be avoided by recollecting that the oxalate may be converted by heat into carbonate of lime, which dissolves with effervescence in acids from which it is not precipitable by ammonia, while the phosphate of lime is unaffected by heat, and dissolves without effervescence in hydrochloric acid from which it may be thrown down by ammonia. When carbonate of lime is associated with oxalate and phosphate of lime, the calculus dissolves with effervescence in hydrochloric acid both before and after heating. In this case the oxalate of lime may be readily overlooked, but on dissolving a fragment of the calculus in hydrochloric acid, and precipitating with ammonia, the oxalate and phosphate of lime are thrown down together, while the carbonate of lime exists in the filtered solution as chloride of calcium, and may be precipitated by oxalate of ammonia. On drying and gently heating the mixture of oxalate and phosphate of lime, the oxalate becomes converted into carbonate. We then dissolve the heated residue in hydrochloric acid, precipitate the phosphate of lime with ammonia, filter, and throw down the lime from the filtered solution with oxalate of ammonia. This lime corresponds with the original oxalate. When the carbonate is mixed with urate of lime, the latter must be taken up with boiling water.

Carbonate of magnesia is only rarely associated with carbonate of lime in urinary calculi, although Berzelius supposes that they always occur together. In order to separate them, they must be dissolved in hydrochloric acid, and the chloride of magnesium then taken up by alcohol.

An analysis of a calculus containing a considerable amount of carbonate of magnesia is given in p. 642.

This salt is of frequent occurrence in calculi of the lower animals.

[*Urostealith.* We have already (see page 542) noticed Heller's discovery of urostealith.]

The concretions that were discharged were round and had not the appearance of being fragments of a larger calculus; in consequence of the locality of the pain it was presumed that they were renal calculi. Altogether a little more than a drachm of urostealith was collected. The concretions varied from the size of a hempseed to that of half a small nut. Most commonly they were of the size of a pea, and either consisted of pure urostealith or had an outer coating of ammoniac-magnesian phosphate.

Urostealith is most readily detected by the effects of heat and combustion. A fragment placed on platinum foil and heated remains for some time solid, then commences to fuse without thoroughly melting, swells, and diffuses much vapour, giving off an extremely peculiar and pungent odour, resembling that of shell-lac and benzoin. The odour is so strong as to be distinctly evolved by the smallest piece of urostealith. After fusing and swelling up, it catches fire (if touched by the flame of the lamp,) and burns with a clear yellow flame. A voluminous coal is left which, when thoroughly burned, leaves a very minute alkaline ash, consisting principally of lime.

When boiled in water urostealith becomes soft but does not dissolve. Warm alcohol dissolves it, but with difficulty; when the alcohol is evaporated and the residue burned the fragrant odour is developed. Ether dissolves it pretty freely; on evaporation the urostealith is left in an amorphous form, and on continuing a gentle heat it assumes a well-marked violet tint. It dissolves readily in a hot solution of caustic potash, forming a brown soap; and on treating this solution with an acid the urostealith again separates as amorphous fat. The carbonates of potash and soda act similarly but more slowly. When heated with nitric acid it yields a colourless solution, a slight quantity of gas being developed: on treating the residue (after evaporation) with ammonia or potash it becomes of a dark-yellow colour.^{1]}

On the laminæ of vesical and renal calculi, and on their quantitative analysis.

In the analysis of urinary calculi it is of the greatest importance to observe the order in which the different laminæ were deposited, and in connexion with this subject, and with the relative proportion in which different sorts of calculi occur, we may especially refer—1, to Brand's² paper on the urinary calculi in the Hunterian Museum; 2, to Marcet³ on the calculi at Guy's Hospital; 3, to Wood⁴ on the calculi at the Canterbury Hospital, the Windmill Street School, and Mr. Cross's collection; 4, to Yellowly,⁵ and 5, to Marcet, for their account of the Norwich Hospital collection; 6, to Henry⁶ on the Manchester collection; 7, to Smith on the Bristol collection; 8, to Rapp⁷ on the Swabian collection; 9, to Lecanu and Segalas⁸ on Segalas's collection; 10, to Scharling on the calculi in the Copenhagen Museum; and, 11, to Taylor⁹ on the calculi in the Museum at St. Bartholomew's Hospital.

¹ Heller's Archiv. für physiologische und pathologische Chemie, vol. 2, pp. 1-12.

² Philosophical Transactions, 1808.

³ An Essay on the Chemical History and Medical Treatment of Calculus Disorders.

⁴ London Medical and Physical Journal, vol. 57.

⁵ Philosophical Transactions, 1829.

⁶ Medico-Chirurg. Transactions, vol. 10.

⁷ Naturwissenschaftliche Abhandlungen. Tübing. 1826.

⁸ Journal de Pharmacie, 1838, p. 463.

⁹ London and Edinburgh Philosophical Magazine, 1838.

The following table affords a view of the relative proportions in which the most common calculi occur:

According to	Oxalates.	Uratos.	Phosphates.	Total.
1. Brand, in Hunterian Museum =	1 : 13.5	1 : 246	1 : 2	150
2. Marcket, in Guy's Hospital	1 : 3	1 : 4	1 : 3	87
3. Wood, in Canterbury Hospital	1 : 3	1 : 1.18	1 : 7	167
4. Yellowly, in Norwich Hospital	1 : 2.9	1 : 3	1 : 76	329
5. Marcket " ditto	1 : 3	1 : 2.7	1 : 32	181
6. Henry, in the Manchester Hosp.	1 : 10.33	1 : 2.2	1 : 65	187
7. Smith, in the Bristol Hospital	1 : 3.33	1 : 3.33	1 : 10.89	218
8. Rapp, in Swabia	1 : 1.43	1 : (11.5) 1.21	1 : 10.1	81
9. Scharling, in Copenhagen Museum	1 : 6.6	1 : 1.6	1 : 6.2	155

The following Table contains the results collected and published by Martin, in his Inaugural dissertation (*de Lithogenesis*), in which I have also incorporated the subsequent investigations of Lecanu and Segras, Scharling and Taylor.

(The figures at the head of the Table refer to the number of calculi of each kind occurring in each collection.)

Urate of lime, urate of ammonia and oxalate of lime	Phosphate	
Crytin		
Phosphate of lime	Earthy phosphates	
Ditto		
Phosphate of lime with oxalate of do.		
Ditto with carbonate of do.		
Ammoniacal-magnesian phosphate		
Ditto	Oxalate of lime	
Ammoniacal-magnesian phosphate		
with oxalate of lime		
Ammoniacal-magnesian phosphate and phosphate of lime	Earthy phosphates	
Earthy phosphates		
Ditto		
Ditto	Oxalate of lime	
Ditto	Uric acid	
Ditto	Phosphate of lime	
Earthy phosphates with uric acid		
Carbonate of lime		
Laminated calculi of unknown com- position		
Mixed calenii		
Oxalate of lime, oxalate of magnesia, ammoniacal-magnesian phosphate, and phosphate of lime		
Urate of ammonia	Oxalate of lime	
Oxalate of lime	Uric acid	
Silica		
Silica with carbonate of lime		
		Urate of ammonia
		Oxalate of lime
150	87	167
329	181	187
81	81	81
160	160	129

I now proceed to give one or two analyses of human calculi as illustrations of their general character.

I analyzed the remarkable calculus alluded to in pp. 626 and 633. I examined, 1st, the external layer; 2d, the inner, tuberculated nucleus; and 3d, the minute round nucleolus. I have likewise analyzed (4th) a calculus of uric acid.

	Anal. 160. Cortex.	An. 161. Nucleus.	An. 162. Nucleolus.	An. 163. Uric acid calculus.
Water	24·5	10·0	3·7	3·0
Solid residue	75·5	90·0	96·3	97·0
Earthy phosphates	70·5	1·1	—	—
Oxalate of lime	—	76·1	—	—
Uric acid	—	—	91·2	92·6
Alkaline urates	1·0	0·5	1·3	3·2
Animal matter	3·5	12·8	3·5	—
Fat and extractive matter	a trace	a trace	—	1·0

The animal matter in the cortex contained a little silica and peroxide of iron; and in the nucleus, a large quantity of dark brown colouring matter.

Uric acid calculi contain:

	According to				
	Taylor.	Joss.	Laugier.	Von Bibra.	
Uric acid	60·0	70·0	10·0	84·69	96·10
Urate of ammonia	—	—	40·0	9·03	—
Urate of lime	—	10·3	—	—	—
Phosphate of lime	10·0	—	—	—	—
Ammoniaco-magnesian phosphate	20·0	—	—	1·12	—
Phosphate of ammonia	—	—	5·0	—	—
Oxalate of lime	—	—	15·0	0·95	—
Ammoniacal matter and water	19·0	10·0	20·0	1·80	1·60
A substance soluble in ether	—	0·5	—	0·81	0·50
" " alcohol	—	—	—	—	0·41

Calculi in which the earthy phosphates and carbonates predominate have been analyzed by Fromherz and Lindberson:

Fromherz.	Lindberson.
Carbonate of lime	91·0
Phosphate of lime	3·0
Albumen and fat	4·0
Urato of soda	—
Basic phosphate of lime	—
Ammoniaco-magnesian phosphate	—
Carbonate of lime	—
Carbonate of magnesia	—
Albumen	—

[Calculi in which oxalate of lime predominates have been analyzed by Scharling:]

	1.	2.
Oxalate of lime	37	63·5
Phosphate of lime	—	6·2
Ammoniaco-magnesian phosphate	39	—
Water	10 {	30·3
Organic matters	13 {	—

See also analysis 161, and the above analysis of Laugier.]

Cystic calculi have been analyzed by Taylor and Bley:

	Taylor.	Bley.	
Cystin	10·0	62	—
Ammoniaco-magnesian phosphate	10·0	366	75·0
Phosphate of lime	38·0	—	7·0
Carbonate of magnesia	—	57·1	—
Uric acid	—	—	180
Animal matter and loss	42·0	—	—

Both the calculi analyzed by Bley were taken from the bladder of the same man; the first weighed 1·75, and the second 2 grains.

URINARY GRAVEL.

Gravel has naturally the same composition as calculi; uric acid is, however, the most frequent constituent. In form, gravel is round or angular, not unfrequently crystalline; its colour is most commonly red, but sometimes pale yellow, gray, or brown. The rules already given for the analysis of calculi apply equally to gravel. After having ascertained by the blowpipe whether the gravel is perfectly destroyed by heat, or whether it leaves an ash that burns white, we then proceed in accordance with the directions given in p. 620. Uric-acid gravel is frequently crystalline, and red or purple, but occasionally of a bright yellow colour, or white. The urine from which it separates is concentrated, highly coloured, and has usually a strong acid reaction.

White gravel is usually composed of phosphate of lime with ammoniaco-magnesian phosphate, and occasionally of oxalate of lime. The ammoniaco-magnesian phosphate crystallizes in beautifully regular prisms, (often of considerable size,) as depicted in fig. 25, and the oxalate in minute globules, or in octohedra, as represented in fig. 36. Phosphate of lime and ammoniaco-magnesian phosphate almost always occur together; oxalate of lime sometimes occurs by itself, and sometimes alternates with the earthy phosphates. Gravel consisting principally of the earthy phosphates is sometimes mixed with urate of ammonia, which latter readily dissolves when heated in water.

I have alluded to the analysis of this kind of gravel in my remarks on urinary sediments in p. 431. The urine in which this white earthy gravel is formed, is either neutral or alkaline, never acid.

Magendie describes a species of gravel containing hairs, (gravelle pileuse,) consisting of phosphate of lime, ammoniaco-magnesian phosphate, and a little uric acid. It is possible that the hair may have been introduced from without, and thus be a mere accidental constituent. When cystin occurs as gravel, it almost always assumes the regular crystalline form that is so characteristic of that substance. Cystic gravel is of a yellow colour, and appears crystalline even to the naked eye.

Lecanu¹ analyzed Segalas' collection of 110 specimens of gravel. Seventy-nine of them (passed by 20 patients) consisted of uric acid with traces of ammonia and organic matter, which, however, in five

¹ Journal de Pharmacie, Sept. 1838.

cases were found only in the cortex, the nucleus consisting of pure uric acid. One minute calculus passed at the same time with others of pure uric acid, had a nucleus of oxalate of lime, and a thick cortex of uric acid. Five calculi from different patients, consisted of oxalate of lime without earthy phosphates, but with some uric acid; nine from different patients consisted of oxalate of lime and earthy phosphates; three from two patients consisted of phosphate of lime and ammoniaco-magnesian phosphate, without uric acid; four from the same patient consisted only of earthy phosphates; four from two patients consisted of ammoniaco-magnesian phosphate, without any appreciable traces of lime; three from two patients, of cystin. A calculus, the size of a pea, discharged with uric acid gravel from a man aged 62 years, was soft and white, soluble in water and alcohol, fusible, when heated evolving an odour of burned sugar, and containing a brown nucleus, formed apparently of a grain of corn. No cases of carbonate of lime were observed in this collection.

[Schlossberger has recently directed attention to the frequent occurrence of gravel, (urate of ammonia) in the tubuli uriniferi of newborn children. He found it in 18 out of 49 cases.]

Preputial and urethral calculi have been analyzed by Romer: fifty-one concretions of this sort, weighing in all 158 grains, were removed from a child with natural phymosis. They consisted of uric acid, associated with phosphate of lime and some connecting animal matter.

URINARY CALCULI OF ANIMALS.

Calculi are by no means uncommon amongst the lower animals, and it has been stated that rats are especially liable to this form of disease. Generally speaking the constituents are much the same as in man, except that no uric acid occurs in the calculi of the herbivora, which consist for the most part of earthy phosphates and carbonates.

In a wild cat, Fourcroy and Vauquelin found a renal calculus of phosphate of lime. The vesical calculi of dogs consist for the most part of phosphate of lime and ammoniaco-magnesian phosphate, with a little animal matter. (Marcket, Brände, Wollaston, and Prevost.) Brände found 30 parts of ammoniaco-magnesian phosphate, 64 of phosphate of lime, and 6 of animal matter. Lassaigne found 53 parts of oxalate of lime, 13 of phosphate of lime, and 39 of animal matter: in another calculus he found 97% of cystin. Two urinary concretions from these animals, examined by myself, were white and somewhat crystalline; they consisted principally of phosphate of lime with a little carbonate of lime. In a renal calculus from a dog, Lassaigne found 58.0 parts of uric acid, 30.8 of urate of ammonia, 1.1 of oxalate of lime, and 10.1 of phosphate of lime. Calculi from consist, according to Marcket, of ammoniaco-magnesian phosphate

and phosphate of lime; according to Fourcroy, of oxalate of lime; and, according to Morand, of phosphate, carbonate, and oxalate of lime. Vesical calculi of hares consist, according to Marcet and Brände, of phosphate and carbonate of lime. Vesical calculi of swine consist chiefly of carbonate and phosphate of lime, and ammoniacomagnesian phosphate; according to Yellowly also, of oxalate of lime. The renal calculi of horses consist of carbonate and phosphate of lime in very variable proportions; Gurlt found 92·0% of the former, and 0·9% of the latter; while Brände found 22% of the former, and 76% of the latter: their vesical calculi are composed, according to Brände and Marcet, of the same constituents: a specimen, analyzed by Buchholz, likewise contained ammoniacomagnesian phosphate, silica, sulphate of lime, and carbonate of magnesia: a calculus, analyzed by Wackenroder, contained 72·47 parts of carbonate of lime, 3·52 of carbonate of magnesia, 3·25 of sulphate of lime, 1·91 of phosphate of lime, 17·10 of mucus, and 1·40 of water. Vesical and renal calculi of oxen consist, according to Rapp, Brände, and Gmelin, of carbonate of lime. A calculus, analyzed by Wurzer, contained 81·4 parts of carbonate of lime, 6·2 of phosphate of lime, 4·3 of carbonate of magnesia, ·009 of peroxide of iron, and ·001 of peroxide of manganese. The same chemist found in a calculus taken from the urethra of an ox, 60 parts of carbonate and phosphate of lime, 38·2 of silica, and 1·8 of peroxide of iron. In a very hard concretion taken from the urethra of an ox, I found a large proportion of carbonate of lime, mixed with a little phosphate of lime and silica.

[The following analyses have lately been made by Von Bibra:

	Calculus from ureter of a horse.	Calculus from bladder of swine.		
		1.	2.	3.
Carbonate of lime	- - 87·63	78·81	- -	- -
Carbonate of magnesia	- -	9·31	- -	- -
Ammoniacomagnesian phosphate	6·61	- -	93·27	90·41
Phosphate of lime	- -	- -	2·10	6·31
Sulphate of lime	- - 1·64	- -	- -	- -
Phosphate of magnesia	- -	0·90	- -	- -
Organic matter taken up by potash	0·20	- -	0·10	0·20 ¹
" " alcohol	- -	0·30	- -	- -
Fat	- - 0·30	0·21	0·20	- -
Water and loss	- - 1·62	10·47	4·33	3·09
Calculus from bladder of ox.				
Carbonate of lime	- - 61·66		64·6	
Carbonate of magnesia	- - 30·78		28·3	
Fat	- - 0·80		0·2	
Water, loss, and traces of iron	- - 6·76		6·9	
Do. from urethra of ox.				

Lassaigne, who as far back as the year 1828 published a memoir on the calculi occurring in the dog, has recently detected a very singular specimen of concretion found in the kidneys, ureters, and bladder of a mastiff-bitch that died from dropsy. The calculi were irregular in shape and of a beautiful glass-green colour. They contained :

¹ Uric acid was taken up by the potash in this instance.

Urate of ammonia	:	:	:	87·0
Green bile-pigment	:	:	:	12·1
Phosphate of lime	:	:	:	a trace.

These calculi are not only remarkable for having uric acid as a constituent—a thing of rare occurrence in those animals, but for having associated with it a principle peculiar to the bile.¹)

Concretions are likewise found in fishes, especially in the sturgeon; they are usually somewhat flattened, and marked with depressions; externally they are of a dull yellow colour; internally they are nearly colourless, and the section exhibits a concentric, radiating, and beautifully crystalline arrangement. Klaproth² analyzed a concretion of this nature weighing seven ounces; it burned to a white ash before the blowpipe, and ultimately fused; it dissolved in nitric acid without effervescence, and contained 71·5 parts of phosphate of lime, 0·5 of sulphate of lime, 2·0 of albumen, and 24·0 of water. In a urinary calculus from a boa constrictor, Wurzer found 40 parts of uric acid, 18 of urate of ammonia, 9 of urate of soda, 19 of phosphate of lime, 10 of albumen, 3 of organic matter, and 1 of iron with traces of manganese.

Intestinal Concretions in Man.

From the researches of Dr. Jäger,³ it appears that intestinal concretions (which are of much rarer occurrence than urinary calculi) consist of earthy phosphates and fatty matters. In conducting an analysis of an intestinal concretion, we proceed in much the same manner as in the case of a fixed urinary calculus. If cholesterol is present, the concretion must be extracted with ether, which, on evaporation, leaves that constituent mixed probably with other fats; to obtain it in a state of purity we must saponify the other fats with potash, remove them with water, and dissolve the residual cholesterol in boiling alcohol, from which it separates almost entirely on cooling. The other fats may be extracted by decomposing their soaps with hydrochloric acid, and collecting the liberated fatty acids. If biliferous acid is present, it may be extracted with alcohol after the fats have been removed by ether, and it may be separated after evaporation of the alcohol by digestion with dilute sulphuric acid. Boil-

¹ Bulletin de l'Académie de Médecine, Dec. 1842.

² Wöhler has recently analyzed a portion of a similar, if not the identical concretion. In 100 parts he found:

	According to $\text{Ca O, PO}_4 + 5 \text{ HO.}$			
Phosphoric acid	-	-	-	41·34
Lime	-	-	-	31·66
Water	-	-	-	26·26
Organic matter	-	-	-	0·74

Hence this concretion consists of the neutral phosphate of lime with five atoms of water, or $\text{Ca O, PO}_4 + 5 \text{ HO.}$ whereas common bone earth is $2 \text{ Ca O, HO, PO}_4 + 2$ (3 Ca O, PO_4) Wöhler suggests the probability of this salt occurring in the place of ordinary bone-earth in the bones of these fishes.]

³ Ueber die Darmsteine des Menschen u. d. Thiere, Berl. 1834.

ing water will take up extractive matter, traces of chloride of sodium, chloride of calcium, and possibly urate of ammonia, a salt once observed by Brugnatelli in intestinal concretions passed in large quantity by a woman. When various organic matters, as for instance woody fibre, hair, &c. occur in these concretions, the earthy constituents must be dissolved in dilute hydrochloric acid, which leaves these organic matters unaffected.

Intestinal concretions are usually round or oval, but when several occur together their rounded form is often destroyed. In size they vary extremely; Renton describes one weighing four pounds, but from two to four ounces appears the ordinary weight. In colour they are most commonly yellow, but sometimes more or less gray or brown. Internally they present a laminated appearance like that of the earthy phosphate calculi, or assume a radiating character, when they contain woody fibre or hair. Their nucleus is usually a foreign body, a fruitstone, a splinter of bone, a needle, or woody fibre. Children describes a calculus that was formed in the colon, round a plum-stone as a nucleus. It contained phosphate of lime 45·34, ammoniac-magnesian phosphate 5·16, carbonate of lime 25·20, resinous matter 3·90, woody fibre 20·30. It likewise contained traces of hydrochloric and sulphuric acids. The cortex of another incrusted plum-stone contained phosphate of lime, albuminous matter, fat, and a sulphur compound.

An intestinal concretion examined by Davy consisted of ammoniac-magnesian phosphate, phosphate of lime, carbonate and sulphate of lime with traces of silica 56; fibrous matter 41; animal matter 2·5.

A concretion found in the intestines of a boy who had taken carbonate of magnesia for a long period continuously, contained no nucleus, neither did it present the ordinary laminated appearance; it consisted entirely of magnesia.

The flattened concretions found by Schönlein in the intestinal ulcers of a patient with enterophtisis consisted, according to Kastner, of phosphate of lime, urate of ammonia, and animal matter.

Fatty matters combined with earthy phosphates are sometimes discharged in large quantities: hard concretions of this nature, varying from the size of a pea to that of a musket-ball, somewhat compressed, smooth, a yellow waxy appearance, and internally white and horny, were passed by a phthisical girl, and consisted, according to Lassaigne, of 74 parts of acid fatty matters, margarin and olein, 21 of a substance resembling fibrin, 4 of phosphate of lime, and 1 of chloride of sodium; a similar mass analyzed by Robiquet contained 60 parts of a fatty matter resembling spermaceti, 30 parts of phosphate of lime, and 8 of animal matter. I have likewise had opportunities of examining substances of this nature discharged by the rectum, but they were soft, and had a caseous appearance. They formed irregular, whitish, easily compressible, greasy masses; contained a large quantity of acid fat (margarin, olein, butyrin, and fibrous matter;) and

left a large amount of ash, consisting for the most part of phosphate of lime. (See p. 586.)

Calculi consisting of cholesterin with biliary resin and colouring matter are sometimes passed from the intestines, but as they must have had their origin in the gall-bladder, they will be considered under the head of biliary concretions.

Davy has found in intestinal concretions a large amount of fibrous matter; in one instance it amounted to 78%, combined with 21·5% of saline matter, and 0·5% of yellow pigment. In another case it amounted to 74·4%, and was associated with 17·2% of resinous matter, 1·4% of brown faecal matter, and 7% of salts.

Laugier has observed hair in these concretions, matted together so as to form thick pilous masses.

[An essay on this subject by Dr. Douglass MacLagan, containing several original analyses, and published in vol. i. of 'The Edinburgh Monthly Journal of Medical Science,' may be consulted with advantage.]

Intestinal Concretions in Animals.

Intestinal concretions are by no means rare either in the carnivora or herbivora; they seem to be especially common in horses. They consist principally of the most insoluble salts that occur in the food, which instead of being uniformly distributed throughout the whole of the chyle, are collected at particular points, or else after having been dissolved in the stomach, are precipitated in the small intestines by the free alkali of the bile, and settle around any nucleus they may meet with. The principal constituents of intestinal concretions are phosphate of lime, phosphate of magnesia, ammoniaco-magnesian phosphate, and occasionally the carbonates of lime and magnesia. Gurlt¹ remarks that the reddish gray concretions found in the stomachs of horses sometimes attain a very considerable size; (he mentions a case in which a concretion weighed 14 pounds;) they consist of concentric laminæ, and are very hard. In horses they have occasionally a bluish-gray tint.

I have analyzed a concretion taken from the cæcum of a cart-horse; it was round, perfectly smooth, of a grayish-yellow colour, weighed about 12½ ounces, was 3 inches and 7 lines in diameter, 11 inches in circumference, and consisted of 3 strata which were deposited round a fragment of granite. All three laminæ were composed of ammoniaco-magnesian phosphate with a little of the alkaline phosphates, but without any phosphate of lime. The second lamina had a radiating structure, and between the rays woody fibres might be detected. The central portion, about the size of a walnut, presented the appearance of a brown urinary calculus; the outer layer closely resembled common jasper. The analysis yielded:

¹ Patholog. Anatomie des Haussäugethiere, p. 35.

	Analysis 164.
Ammoniaco-magnesian phosphate	81.11
Phosphates of potash and soda	1.50
Sand	0.60
Vegetable fibre	0.58
Alcohol-extract	0.50
Water-extract	0.50
Water and loss	15.19

I have analyzed some of the concretions in the museum of the Berlin Veterinary College. Some small, flat, reniform, grayish brown concretions from the colon of a horse consisted chiefly of pure ammoniaco-magnesian phosphate aggregated around very minute nuclei of metallic lead. A flat, grayish brown concretion, of the size of a pigeon's egg, taken from the colon of a horse, contained in addition, some phosphate of lime; the nucleus was a fragment of brick. The external layer of a gastric concretion from a horse, weighing 8 pounds, consisted principally of ammoniaco-magnesian phosphate combined with some phosphate of lime, and the external layer of a large calculus found in the intestines had a perfectly similar composition. Some small, triangular, smooth and white concretions from the stomach of a Dutch mastiff, when fractured, presented a beautiful, white, sparkling, crystalline character, and were composed of the same constituents; the quantity of phosphate of lime was, however, very small. The external layer of an intestinal concretion from an ass exhibited white and chalky lamellæ, with little firmness. It consisted of carbonate of lime, with a small admixture of phosphate of lime.

Carbonate of lime, such as I observed in the concretion from the urethra of an ox, and in the above mentioned intestinal concretion from an ass, has been very rarely observed; Pearson detected it in a gastric calculus from an ape; Kinast in a similar concretion from a cow; Pearson and John in the intestinal concretion of a horse; and Vauquelin and Fourcroy in bezoars. Uric acid was observed by Fourcroy in the intestinal concretion of a horse.

Concretions formed of agglomerated hairs are often observed, especially in cows. They are usually brown and polished, but not hard.

[Several analyses of intestinal concretions have been recently published by Von Bibra.¹ We give the two following as illustrations of their composition:

	Concretions from intestines of horse.		
Ammoniaco-magnesian phosphate	-	-	93.10
Phosphate of lime	-	-	1.18
Matters taken up by alcohol and ether	-	-	0.43
" potash	-	-	0.36
Chloride of sodium	-	-	0.63
Phosphate of soda	-	-	0.31
Water, vegetable fibre, traces of iron, and loss	-	-	3.99

¹ Simon's Beiträge, pp. 404, 12.

		Concretion from stomach of a miller's horse.
Ammoniaco-magnesian phosphate	-	93.02
Phosphate of lime	-	1.01
Matter taken up by alcohol	-	0.41
" by potash	-	0.33
Sand	-	0.40
Chloride of sodium and traces of phosphate of soda	-	0.51
Water, traces of iron, vegetable fibre, and loss	-	4.32

The occurrence of phosphate of soda is remarkable, as that salt does not occur in the gastric juice.]

Peculiar concretions are found in the intestinal canal of an herbivorous animal inhabiting Persia and Thibet. They are termed bezoar stones; they are round or oval; in colour they are dark green, brown, or black; they are polished on the surface, and consist internally of concentric laminæ. Some are soluble, others insoluble in alcohol, but all dissolve in caustic potash. The researches hitherto made with these concretions throw very little light on their real composition. They are usually green in the interior, do not fuse on being heated, and give off a not disagreeable odour. Hot water extracts a yellow matter; caustic potash dissolves them rapidly, forming a grayish brown solution, from which a dull green precipitate is thrown down on the addition of an acid.

This precipitate dissolves in nitric acid, producing a red tint, which rapidly changes to a yellow. Berzelius is of opinion that the principal mass of bezoar consists of biliary fat and resin, mixed with other fatty matter, and held together by intestinal mucus.¹

Gall-stones in Man.

Biliary concretions are of very common occurrence in the human subject. They consist principally of cholesterin with a small amount of other fats, bilifellinic acid or biliary resin mixed with some bile-pigment, and mucus. In analyzing a gall-stone, we first reduce it to a fine powder, which is a matter of no difficulty, and heat it on the water-bath in order to expel all moisture. The powder is then extracted with water, which takes up bilin with bilifellinic acid, and probably a little extractive matter; these are obtained by evaporating the water. The portion not taken up by water must be again dried and treated with hot, pure ether, which extracts the fat. We evaporate the ether, and dissolve the residue in hot alcohol, from which cholesterin crystallizes on cooling; after the removal of the cholesterin the evaporated alcohol yields the other fats as fatty acids. The residue insoluble in ether is now extracted with boiling anhydrous alcohol, which dissolves the biliary resin. On evaporating the alcoholic solution and treating the residue with cold alcohol, we obtain a solution of biliary resin (fellinic and cholinic acids, and dyslysin.)

¹ [For further information on this subject the reader is referred to a paper by Guibourt, in vol. 16 of the 'Comptes Rendus,' and to observations 'on a new organic acid in bezoar stones' by Lipowitz, in Simon's Beiträge, p. 462.]

The portion unacted on by alcohol may still contain biliphæin and biliary mucus; the former is soluble in carbonate of ammonia, the latter in a solution of potash.

Human gall-stones vary from the size of a hemp-seed to that of a pigeon's egg; they are round, or, if several occur together, angular and flat-sided, each facette lying in close apposition with that of the adjacent calculus. Their surface is smooth, their colour brown or yellow. Internally they present a decidedly crystalline character, they are white or yellow, and often contain a minute cavity in the centre, of a darker colour than the rest of the concretion, and presenting an incrusted appearance.

Witting¹ found in a human gall-stone cholesterin 50; resin and colouring matter insoluble in ether 35; carbonate of lime 8, water 5.

The following analyses of human gall-stones were made by Glaube and Brande:

	Glaube.	Brande.		
		1.	2.	3.
Cholesterin :	56	81.25	69.76	81.77
Biliary resin :	8	3.12	5.66	3.83
Bile-pigment :	15	9.38	11.38	7.57
Albumen with mucus and salts extractable by water	—	—	—	3.83
Coagulated albumen :	9	—	—	—
Biliary mucus :	12	6.25	13.20	—

In addition to the ordinary constituents Von Bibra² found 1.5% of alumina with iron, and 1.4% of carbonate of lime in a biliary calculus; and Witting, as I have already observed, detected a considerable amount of the latter constituent in a concretion of this nature. An extraordinary quantity of this earth was found by Bally and Henry in a gall-stone; it consisted of carbonate of lime with traces of carbonate of magnesia 72.70, phosphate of lime 13.51, mucus, with a little peroxide of iron and bile-pigment, 10.81.

[Schmidt and Wackenroder have recently published analyses of human biliary calculi, consisting principally of colouring matter. Archiv der Pharmacie, vol. 41, p. 291.]

Berzelius mentions another kind of gall-stones, consisting principally of carbon; at least it is insoluble in water, alcohol and ether, acid and alkaline fluids; when heated to redness in a retort, undergoes no alteration, but when burned in oxygen, after giving off slight traces of smoke, takes fire, and burns without flame or residue, with the formation of carbonic-acid gas.

I have recently examined a biliary calculus found in the gall-bladder of an officer who died from cerebral and spinal irritation, and incipient softening of the nervous tissue: in contradistinction to the general rule, it contained mere traces of cholesterin, and was principally composed of biliary resin, and modified colouring matter.

[Bertazzi³ has recently announced the discovery of copper as a constant ingredient of gall-stones. He analyzed fourteen of these concre-

¹ Archiv der Pharm. vol. 25, p. 292.

² Journ für prakt. Chemie, vol. 12, p. 311.

³ Polli's Annali di Chimica. Milan. Juglio, 1845, p. 32.

tions sent to him by Polli, and found it in every instance. The amount of copper seemed to stand in a direct ratio to the amount of bile-pigment in the calculus. Thus, on incinerating an almost black spongy-looking concretion, so large a quantity of copper was present in the ash, that an iron cylinder, nearly a line in diameter and four inches long, after immersion for a few seconds in a dilute acid solution of the residue, was entirely coated. When, on the other hand, merely the nucleus or the external layer contained pigment, the indications of the presence of copper were comparatively slight, and he is of opinion that perfectly white concretions are entirely devoid of this constituent. With the view of ascertaining whether copper could be detected in the bile, Bertazzi analyzed the fluid collected from the gall-bladders of ten persons. He could not, however, detect any indications of the metal.

The above statement respecting the presence of copper in biliary calculi has been subsequently confirmed by Heller.^{1]}

Biliary Concretions in Animals.

Biliary concretions are very common in cattle: Gurlt never observed them in horses, and only once detected a calculus of this nature in a dog. The biliary concretions of cattle differ considerably from those of man; they consist for the most part of biliary pigment and resin with a little cholesterol. In analyzing the biliary concretions of oxen we must pursue the method already prescribed, but at the same time we must not overlook the circumstance that an independent (lithofellinic) acid has been noticed by Göbel as occurring in them, which is not found in human biliary calculi. It is soluble in boiling alcohol and crystallizes on cooling; on heating it fuses, becomes decomposed, and burns. It is insoluble in acetic and hydrochloric acids, but dissolves in caustic potash, with which it forms a soap that develops an odour resembling amber. It separates from this soap in a crystalline form on the addition of an acid. These crystals are of a rhombic-prism form, dissolve in alcohol and ether but not in water, fuse at a high temperature, and combine with alkalies to form soaps, which are slightly soluble in water, but dissolve readily in alcohol and ether. This acid has also been observed by Wöhler, and I have likewise detected a substance in the biliary calculi of cattle, which, as far as I have yet been able to analyze it, seems to be identical with lithofellinic acid. It is probable that lithofellinic acid is of more frequent occurrence than has hitherto been supposed; it ought, therefore, to be sought for in all biliary calculi, more especially in those of cattle.

The biliary calculi of cattle vary from the size of a pea to that of a pigeon's egg; they may be easily pulverized, the powder varying in colour from a dull green to a clear brown, and possessing a decidedly bitter taste. On boiling the pulverized calculus with alcohol, the

¹ Archiv für physiolog. und patholog. Chemie, vol. 2, p. 298.

alcohol becomes coloured yellow or green, and leaves on evaporation a small quantity of biliary resin and cholesterin. The powder, after extraction with alcohol, yields to caustic ammonia or to its carbonate, a certain amount of its colouring matter, but not so much as is taken up by even a very dilute solution of caustic potash. The alkaline solution is of a yellowish brown tint, but soon changes into a green. On the addition of hydrochloric acid to the alkaline solution the colouring matter is precipitated in the form of gray flocculi which dissolve readily in alcohol, leaving in an insoluble state the mucus that had been dissolved by the potash.

Schübler and Michel¹ analyzed a concretion found in a cystic tumour in the liver of a man. It was of a red colour, and was composed of 25 parts of yellow, slightly saponifiable fat soluble in ether, and of 75 parts of red colouring matter. This colouring matter presented several remarkable characters: and Berzelius regards it as a morbid form of the ordinary bile-pigment.

Salivary Calculi, Tartar, &c.

In man salivary calculi are of rare occurrence, but the formation of tartar on the teeth is continually observed: it consists of earthy phosphates, epithelium-scales, a little ptyalin, and fat, and when examined under the microscope there are seen abundance of pavement epithelium and mucus-corpuscles with fat-vesicles, and, in addition to these, numerous long acicular bodies and infusoria of the genera *Vibrio* and *Monas*.

According to Berzelius tartar is composed of earthy phosphates 79·0, salivary mucus 12·5, ptyalin 1·0, animal matter soluble in hydrochloric acid 7·5.

Vauquelin and Laugier obtained similar results, namely, 66 parts of phosphate of lime with a little magnesia, 9 of carbonate of lime, 13 of salivary mucus, and 5 of animal matter soluble in hydrochloric acid.

Poggiale² analyzed a salivary calculus taken from a man; it was hard, round, tuberculated, of a yellow colour, and easily pulverized. It contained a large amount (94·6) of phosphate of lime, with a little mucus and animal matter.

Wurzer³ analyzed a calculus from the maxillary gland of a man; it weighed three grains, was oval, of a grayish white colour, and consisted principally of carbonate of lime and earthy phosphates, with traces of iron and manganese.

Salivary calculi are of frequent occurrence in the ass and the horse, and are occasionally found in the dog. They consist for the most part of earthy carbonates mixed with a small amount of earthy phosphates and animal matters.

¹ Journal für prakt. Chemie, vol. 8, p. 378.
² Archiv der Pharmacie, vol. 14, p. 254.

³ Journal de Pharmacie, 1839, p. 337.

The following analyses will give an idea of their composition:

		From an ass. Caverton.	From a horse. Lassaigne.	From a horse. Henry.
Carbonate of lime	- - -	91·6	84	86·52
Carbonate of magnesia	- - -	-	-	7·56
Phosphate of lime	- - -	4·8	3	4·40
Animal matter soluble in water	- - -	3·6	9	2·42
Water	- - -	-	3	-

Similar concretions occur in many other parts of the organism. I shall notice a few instances.

Wurzer analyzed a concretion formed in one of the tonsils: externally it was of a grayish white colour, marked with rose-red spots, and verrucose; internally it presented no appearance of lamellæ, although it contained an oval nucleus. It consisted of phosphate of lime 63·8, carbonate of lime 16·7, animal matter 13·3, ptyalin with chlorides of sodium and potassium, 7·1, iron and traces of manganese, 0·1. Daniel has described a hard and dense tumour, containing, however, traces of fibrous tissue, that occurred in the anterior wall of the uterus of a single woman aged 72 years. It contained 35% of animal matter and water, 56% of phosphates of lime and magnesia, 5% of carbonate of lime, and 4% of chloride of sodium and other salts. An earthy deposit in the uterus, analyzed by Wiggers, contained 46·8% of earthy phosphates and carbonates, and 46·1% of fibrin, with a little fat. Poggiale has examined the muscular tissue of a man in whom ossification of the muscles had proceeded to such a length as almost entirely to prevent any voluntary motion. A portion of the ossified *gastrocnemius* contained 58% of organic matter, 32·09% of phosphate of lime, 1·25% of phosphate of magnesia, and 8·66% of carbonate of lime.

Concretions in the brain are very rare. I obtained a concretion of this nature that had formed in the cerebellum; it was about the size of a nut, of an irregular angular form, very solid, and both internally and externally resembled a portion of bone. The whole concretion was enveloped in a fine coriaceous capsule; it consisted principally of phosphate and carbonate of lime, with a little cholesterin. A similar concretion analyzed by John consisted of 75 parts of the phosphates of lime and magnesia, and 25 of animal matter; another, examined by Morin, was composed of cholesterin, coagulated albumen, and earthy phosphates. In a concretion taken from the brain of a horse Lassaigne found 58 parts of cholesterin, 39·5 of coagulated albumen and cellular matter, and 2·5 of earthy phosphates.

[Scherer found in the gritty matter contained in the pineal gland:

Organic matter	-	-	-	22·460
Phosphate of lime	-	-	-	60·321
Carbonate of lime	-	-	-	17·219]

A concretion from the eye of a blind man contained, according to Wurzer, 47·9 parts of phosphate of lime, 9·5 of the carbonates of lime and magnesia, 20·3 of mucus, 0·9 of peroxide of iron, and 11·9 of clear fat resembling butter. A nasal concretion occurring in a

woman aged 57 years was found by Brandes¹ to consist of 79·6 of phosphate of lime, 6·4 of carbonate of lime, and 14 of chloride of sodium, animal matter, and water. It consisted of five portions, weighing altogether 210 grains. It varied externally from a grayish white to a yellowish green colour, and its internal surface was gray and finely granular.

A nasal concretion analyzed by Regnard consisted principally of carbonate of lime, with a little phosphate of lime and animal matter. A specimen analyzed by Geiger consisted almost entirely of earthy phosphates and carbonates, while another examined by Herberger, yielded 46% of dried nasal mucus. A calculus of this nature weighing 81 grains, analyzed by Römer, contained 90 parts of phosphate of lime, 5 of carbonate of lime, and 5 of animal matter with traces of carbonate of soda.²

Concretions formed in the lungs consist also principally of the earthy phosphates and carbonates. A pulmonary concretion analyzed by Sgarzi, contained carbonate and phosphate of lime, carbonate of magnesia, cholesterol, fat, mucus, albumen, peroxide of iron, and silica. A concretion of this nature, that had been expectorated, was analyzed by Brandes; it contained the above mentioned salts, cemented with mucus and albumen.

On examining the lungs of the boy with the osteoid tumour, noticed in p. 605, there was found in them an oval, solid encysted concretion, of the size of a hazel nut. Being anxious to ascertain whether it was allied to the osteoid tumour in its composition, I analyzed it and found in 100 parts:

		Anal. 165.	
			In 100 parts of fixed salts.
Organic matter	-	38·89	
Fixed salts	-	61·11	
Earthy phosphates	-	53·33	87·20
Carbonate of lime	-	7·04	11·50
Soluble salts	-	0·37	0·65

Hence this concretion, in relation to the proportions of its salts, differs only in this respect from the osteoid tumour—that it contains a larger amount of carbonate of lime and a smaller quantity of soluble salts.

[A concretion found in one of the bronchi of a man who died from phthisis was analyzed by Scherer. It had a knotty, white appearance, and was invested with a delicate membrane. It contained in 100 parts:

Organic matter	:	:	:	:	:	20·10
Phosphate of lime	:	:	:	:	:	69·92
Carbonate of lime	:	:	:	:	:	9·09
Chloride of sodium, sulphate and phosphate of soda						0·69

A hard concretion of the size of a pea, attached to the pleura, was analyzed by Schierenberg, and found to contain:

¹ Archiv der Pharmacie, vol. 11, p. 157.

² [Much additional matter on the chemistry of nasal concretions may be found in a paper by Demarquay, in the 'Archives gén. de Médecine,' Juin, 1845.]

Organic matter	-	-	-	-	-	36.967
Phosphate of lime	-	-	-	-	-	55.924
Carbonate of lime	-	-	-	-	-	7.109]

A concretion in the pericardium, analyzed by Petroz and Robinet, consisted of 65.3 parts of basic phosphate of lime, 6.5 of carbonate of magnesia, 4.0 of sulphate of soda, with a little sulphate of lime, and 24.3 of organic matter. Concretions in the mesenteric glands have been analyzed by Wild: they contained 56.61% of phosphate of lime, 2% of carbonate of lime, and 26.28% of cellular membrane and fat. In a calcareous deposition on the peritoneum, Bley¹ found 34 parts of carbonate of lime, 27.66 of carbonate of magnesia, 10.32 of phosphate of lime, and 12.4 of albumen, mucus, and fat. A concretion from the prostate gland, examined by Lassaigne, contained 84.5% of phosphate of lime, with traces of carbonate of lime and animal matter.

I examined an incrustation occurring in the aorta of an old man who died from phthisis pulmonalis; it consisted principally of carbonate of lime and earthy phosphates.

[The ossified arterial membrane in the case of marasmus senilis, mentioned in p. 535 yielded, after careful preparation:

Organic matter	-	-	-	-	7.292
Phosphate of lime	-	-	-	-	63.636
Phosphate of magnesia	-	-	-	-	10.909
Carbonate of lime	-	-	-	-	18.181]

Gouty concretions, which frequently form on the joints of the hands and feet, consist of urate of soda, with a little of the urates of potash and lime, chloride of sodium, and ordinary animal matter. Wollaston was the first to describe their composition correctly. The two following analyses will illustrate their composition:

		Langier. ^a	Wurzer.
Uric acid	-	-	20.0
Soda	-	-	90.0
Lime	-	-	10.0
Chloride of sodium	-	-	18.0
Chloride of potassium	-	-	2.2
Animal matter	-	-	19.5
Water	-	-	10.3

Some gouty concretions, about the size of a pea, were analyzed by Pauquy and Bor, and found to consist of urate of soda, urate of lime, and an albuminous substance, but no chlorides.

[In page 602 there is an analysis of bone in a case of arthritis, by Marchand. The same chemist analyzed a gouty concretion on the lower articulation of the femur. It contained:

Urate of soda	-	-	-	-	34.20
Urate of lime	-	-	-	-	2.12
Carbonate of ammonia	-	-	-	-	7.66
Chloride of sodium	-	-	-	-	14.12
Water	-	-	-	-	6.80
Animal matter	-	-	-	-	32.53

Lehmann analyzed a tophaceous concretion that formed on the metacarpus of a man only 22 years old, but who had suffered from well-

^a Archiv de Pharmacie, vol. 20, p. 212.

^b The loss in this analysis amounts to 16.6.

marked gout. It was, on its removal, soft and tough, white internally, and reddish-brown on its external surface. When dried, it formed a white chalky mass. Under the microscope there were seen innumerable four-sided prisms arranged in stellar groups; these consisted of urate of soda. The concretion, when dried, was found to contain:

Urate of soda	-	-	-	-	52.12
Urate of lime	-	-	-	-	1.25
Chloride of sodium	-	-	-	-	9.84
Phosphate of lime	-	-	-	-	4.32
Cellular tissue	-	-	-	-	28.49
Water and loss	-	-	-	-	3.88

A concretion of this nature, analyzed by L'Heretier, yielded:

Urates of ammonia, soda, and lime	-	-	49
Phosphate of lime	-	-	42
Organic matter and water	-	-	9]

Tubercle.

Chemical analysis has hitherto thrown very little light on the nature of tubercle, or on the mode of its formation. A tubercular mass, analyzed by Preus, contained 19.5 of solid constituents and 80.5 of water. The solid constituents were composed of a substance resembling casein in its relations towards acetic acid and heat, a fat containing cholesterol, and a very small quantity of salts.

In an analysis which I instituted of a mass of tubercle from a horse, I detected a little of the caseous matter noticed by Preus. The tubercular matter was deposited in masses from the size of a nut to that of a pigeon's egg; it varied from a yellow to a flesh colour, and its consistence was such as to admit of its ready division by the knife. Internally it was green and resembled coagulated casein. It was composed of:

Analysis 168.					
Water	-	-	-	-	84.27
Fat containing cholesterol	-	-	-	-	1.40
Spirit-extract with salts	-	-	-	-	1.52
Caseous matter with water-extract	-	-	-	-	1.14
Water-extract and salts	-	-	-	-	3.80
Insoluble constituents	-	-	-	-	4.44

[The following ultimate analyses of tubercle, by Scherer, are highly important in tending to throw light on the chemistry of its formation.

Crude pulmonary tubercle yielded little fat or extractive matter, showing that the morbid process was not far advanced. An ultimate analysis, after the most careful removal of foreign constituents gave:

Carbon	-	-	-	53.888	} which corresponds with the formula C ₄₃ H ₃₆ N ₆ O ₁₄
Hydrogen	-	-	-	7.112	
Nitrogen	-	-	-	17.237	
Oxygen	-	-	-	21.767	

Hence tubercle may be regarded as protein¹ (C₄₃H₃₆N₆O₁₄) from

¹ This is Liebig's formula.

MORBID PRODUCTS.

which five atoms of carbon, one of hydrogen, and one of oxygen have been removed.

A mass of tubercle deposited in the liver, when examined under the microscope, was found to contain round, irregular, nucleated cells larger than pus-corpuscles, and numerous interspersed granules.

In 1000 parts there were contained:

Water	-	-	-	-	896.04
Solid residue	-	-	-	-	173.96
Fat taken up by ether, consisting of olein and margarin	-	-	-	-	18.63
Alcohol-extract	-	-	-	-	91.76
Water-extract with very slight traces of pyin	-	-	-	-	8.34
Insoluble organic residue	-	-	-	-	190.34
Fixed salts	-	-	-	-	4.90

This insoluble portion contained:

Carbon	-	-	-	54.554	} which corresponds with the formula $C_{46}H_{36}N_6O_{12}$
Hydrogen	-	-	-	7.121	
Nitrogen	-	-	-	16.928	
Oxygen	-	-	-	21.397	

Hence it may be supposed to be derived from protein that has lost three atoms of carbon and one of oxygen.

In tubercular masses found in the abdominal cavity, resembling coagulated albumen, there were found:

Water	-	-	-	-	899.89
Solid residues	-	-	-	-	106.18
Fat	-	-	-	-	25.40
Casein and alcohol-extract	-	-	-	-	19.39
Pyin and water-extract	-	-	-	-	6.19
Salts	-	-	-	-	7.43
Crude tubercular matter	-	-	-	-	54.55

which yielded in three analyses:

	1.	2.	3.
Carbon	-	55.290	55.069
Hydrogen	-	7.098	7.004
Nitrogen	-	16.698	16.534
Oxygen	-	20.905	21.393

These analyses correspond with the formula $C_{46}H_{36}N_6O_{12}$; hence tubercle in this case may be regarded as protein from which two atoms of carbon and one of oxygen have been removed.

In this instance, the surface of the liver was coated with a layer of plastic exudation a line and a half thick. This was separated and analyzed in the same manner as the tubercular matter. It contained:

Water	-	-	-	-	731.62
Solid constituents	-	-	-	-	268.38
Fat	-	-	-	-	15.47
Water-extract with pyin and casein	-	-	-	-	4.33
Spirit-extract	-	-	-	-	6.23
Salts	-	-	-	-	5.40
Insoluble organic residue	-	-	-	-	237.96
Containing—Carbon	-	-	-	-	55.190
Hydrogen	-	-	-	-	7.186
Nitrogen	-	-	-	-	16.602
Oxygen	-	-	-	-	21.023

This substance is consequently identical in its ultimate composition with the tubercular matter found in the abdomen.

Tubercular matter from the brain yielded, after purification:

Carbon	-	-	-	54.410	which corresponds with the formula $C_{46}H_{51}N_6O_{14}$
Hydrogen	-	-	-	7.147	
Nitrogen	-	-	-	16.366	
Oxygen	-	-	-	22.077	

That is to say, two atoms of carbon less, and one atom of hydrogen more than occurs in protein.

If in this and the preceding analyses the formulæ for the morbid deposits are calculated in relation to C_{46} , their connexion with the formula for protein will be more obvious to the eye. We shall have:

2 At. of tubercular matter from the lungs	. . . . .	= 2 Pr + NH ₂ + 2 HO + H
2 At. of tubercular matter from the liver	. . . . .	= 2 Pr + NH ₂ + H
2 At. of tubercular matter from the abdomen	. . . . .	= 2 Pr + NH ₂
4 At. of cerebral tubercle	. . . . .	= 4 Pr + NH ₂ + 4 HO + 3 H

Scherer has adopted a similar course of research with other morbid products.

A scrofulous mass found in the abdomen of a child who died from general scrofula, was, after extraction with water, alcohol, and ether, submitted to ultimate analysis. Independently of salts, it yielded:

Carbon	-	-	-	54.125	which corresponds with the formula $C_{46}H_{51}N_6O_{14}$
Hydrogen	-	-	-	7.281	
Nitrogen	-	-	-	15.892	
Oxygen	-	-	-	22.702	

Hence the scrofulous matter may be regarded as formed from protein by the removal of two atoms of carbon and oxygen, and the addition of two of hydrogen, or making the amount of carbon the same in the scrofulous mass and the protein, we have:

$$1 \text{ At. scrofulous matter} = \text{Pr} + \text{HO} + 2 \text{ H.}$$

Carcinoma uteri and scirrus testiculi were examined by Scherer in a similar manner.

L'Heretier has made the three following proximate analyses of scirrus:

			Of breast.	Of uterus.	Of dorsal region.
Water	-	-	29.75	21.15	24.60
Albumen	-	-	28.10	29.85	21.70
Fibrin	-	-	18.80	15.20	27.15
Gelatin	-	-	7.60	—	8.17
Fat	-	-	2.00	—	8.05
Phosphorized fat	-	-	—	6.00	—
Peroxide of iron	-	-	1.15	1.25	traces
Yellow pigment	-	-	—	7.00	—
Salts	-	-	12.60	9.55	10.13]

A fatty tumour analyzed by Nees von Esenbeck¹ contained 23.0 of solid fat, 12.0 of extract of flesh, 11.0 of gum-like animal matter, 23.0 of albumen, 19.0 of phosphate of lime, 2.0 of carbonate of lime, and 1.5 of carbonate of magnesia. It is not stated whether this solid fat contained cholesterol; in all probability it did, as this fat is of frequent occurrence in fatty tumours. In a fatty tumour examined by J. Müller there were acicular crystals mixed with a gray substance which was deposited in vesicles and dissolved in boiling water, from

¹ Kastner's Archiv, vol. 12, p. 460.

which it was not precipitated by acids or the ordinary metallic salts. The crystals were insoluble in acids, water, or alcohol, but dissolved in ether; hence they probably consisted of cholesterol. Another fatty tumour contained some casein precipitable from the aqueous solution by acetic acid.

Incrustations on the surface of the body.

Sore surfaces from which the epidermis has been removed are covered by a fluid which usually consists, according to Berzelius, of serum. This fluid dries up and protects the exposed surface from the atmospheric influence. My own investigations lead me to believe that this fluid differs materially from serum, that it contains a much larger quantity of albuminate of soda, and that its solid residue consists, for the most part, not of coagulated albumen, but of epithelium- and pus-cells.¹ Lassaigne has analyzed the crusts of small-pox; they contained 63—70 parts of coagulated, and 15—14 of uncoagulated albumen, 2—1 of fat, 18—11 of extract of flesh, and 2—2·5 of salts. Wackenroder found uncoagulated albumen in the crusts of tinea capitis.

I have analyzed the crusts which formed on sores on the body of a man with a severe attack of icterus. They appeared as yellow or whitish-yellow scales, or as large shreds of skin, and were very difficult to pulverize. When rubbed with water they swelled, and ultimately formed an emulsive sort of fluid, which did not clear on standing, and in which a very large number of epithelium-scales were suspended. The filtered fluid coagulated very slowly on the application of heat, but became covered with a film during evaporation. It had a faintly alkaline reaction, and was rendered slightly turbid by the addition of an acid, but again became clear on the addition of an excess of the test. It was strongly precipitated by ferrocyanide of potassium, infusion of galls, and bichloride of mercury. On heating the residue, after evaporation with water, it was found to be almost insoluble; alcohol took up some extractive matter with a very little chloride of sodium.

The residue yielded an ash which slightly effervesced on the addition of nitric acid, and contained mere traces of the earthy phosphates and chlorides, but a considerable amount of phosphate of soda. The portion insoluble in water appeared, when examined under the microscope, to consist of epithelium-cells, for the most part more or less injured. Alcohol took up from these scales a little yellow fat which partly separated on cooling: this portion consisted of margaric acid and margarin, while oleic acid remained in solution. The ash left by the direct incineration of the scales contained scarcely appreciable traces of sulphates or chlorides, a little carbonate and a large

¹ [In connexion with this subject a paper 'On Pyin, and its importance in the human Organism,' by Eichholz, in Rust's Mag. für die gesammte Heilkunde, vol. 64, p. 140, may be consulted with advantage.]

amount of phosphate of soda, earthy phosphates, and a trace of iron. Hence these scales contained the ordinary fats and fatty acids, a little uncoagulated albumen, a large quantity of albuminate of soda, some extract of flesh, and a considerable amount of salts, in which the phosphate of soda and earthy phosphates predominated. No bilin could be detected, and only a trace of bile-pigment.

I have recently examined the scales of a person with ichthyosis. They were of a gray or black colour; when placed in water they softened, and on then placing a section under the microscope I found that the abnormal structure was formed of compressed epithelium-scales.

On incineration the scales left an ash containing carbonate and phosphate of lime, and peroxide of iron; the latter was in such abundance as to communicate a yellow colour to the ash. The ash yielded by the incineration of the ordinary thickened skin on the hands and feet is perfectly white, and contains a mere trace of peroxide of iron.

CHAPTER XIII.

FLUID PRODUCTS OF DISEASE.

HYDATIDS are round vesicles filled with fluid, sometimes but not always containing a minute animal (*echinococcus*); these vesicles occur most commonly in the brain or liver. Göbel analyzed hydatids from the liver of a goat; the *echinococcus* was present in large numbers; the fluid contained in the vesicles was clear, yellow, neutral, gave off an unpleasant odour during evaporation, and blackened a silver spatula with which it was stirred. It yielded 1·54% of solid residue consisting of ·04 albumen, 0·24 mucus, and 1·26 salts, namely, carbonate of soda, chloride of sodium, sulphate of potash, and phosphate of lime. The vesicle itself was insoluble in water and alcohol, yielded a little fat to ether, swelled in acetic acid without dissolving, but dissolved in a solution of caustic potash, from which it could be precipitated by the addition of acetic acid.

Collard de Martigny has likewise analyzed hydatids. The fluid contained in them was faintly yellow, and somewhat turbid from the presence of flocculi of albumen, which soon settled to the bottom. Boiling produced a marked turbidity in consequence of the coagulation of albumen. It contained water 96·5, albumen, 2·9, and salts, for the most part of chloride of sodium, 0·6.

The membrane enclosing the fluid was divisible into five laminæ, was insoluble in ether, alcohol, and boiling water, but dissolved, even without the aid of heat, in sulphuric, hydrochloric, and nitric acids, from which it was not precipitated on neutralization with a free alkali; it was not dissolved by acetic acid, and was rendered leathery by infusion of galls.

[Scherer has analyzed the fluid contained in hydatids of the kidney. It was of a brownish yellow colour, threw down a light, flocculent, brown deposit, and evolved an ammoniacal odour.

In 1000 parts there were contained:

Water	-	-	-	-	934.763
Solid constituents	-	-	-	-	65.238
Albumen	-	-	-	15.960	Protein-compounds
Albuminate of soda	-	-	-	10.044	26.004
Alcohol-extract with lactates & ammonia-salts	-	-	-	22.312	Transformed matter
Water-extract	-	-	-	3.797	
Fat	-	-	-	2.042	28.151
Inorganic salts	-	-	-	10.615	
Uric acid	-	-	-	0.413	

Not a trace of urea could be found; it had probably been converted into carbonate of ammonia.]

Cysts may either be filled with a solid matter, as for instance, fat (in which case they form the fatty tumours of which we have already spoken,) or they may contain a fluid.

Collard de Martigny analyzed the fluid contents of a cystic tumour situated between the rectum and the uterus. The fluid was of the consistence of a syrup, of a dirty yellow colour, viscid, and of a sickly odour. When evaporated at a temperature of 104°, it left a brown residue amounting to 12.8%, which softened in water without dissolving, and on heating, gave off an odour of burned horn. On the addition of alcohol to the fluid a thick, elastic, yellow mass was precipitated; which dissolved in water and was again thrown down on adding a dilute acid, but was soluble in an excess of the reagent. The alkalies, sulphate of iron, and nitrate of silver exerted no influence on this solution, but a yellow precipitate was thrown down by nitrate of the protoxide of mercury, tincture of iodine, tannin, and bichloride of platinum. From these imperfect data it is impossible to form any conclusion regarding the true nature of the fluid.

I made an analysis of a thick chocolate-coloured, alkaline fluid, obtained by puncture in a case of ovarian dropsy. Under the microscope there were a considerable number of pus-corpuscles, and a few coloured blood-corpuscles visible. It contained so much albumen that on heating it coagulated, forming thick brown flocculi. The colouring matter is doubtless to be attributed to the presence of hæmato-globulin: the fat abounded in cholesterin.

It contained:

					Analysis 167.
Specific gravity	-	-	-	-	1030
Water	-	-	-	-	925.00
Solid constituents	-	-	-	-	75.00
Fat containing cholesterin	-	-	-	-	1.10
Albumen	-	-	-	-	56.77
Alcohol-extract	}	}	}	-	4.50
Spirit-extract					
Water-extract					
Carbonate of soda, phosphate of lime, }	}	}	}	-	8.89
chloride of sodium and lactate of soda }					
Albuminate of soda	-	-	-	-	7.50

[Scherer has made several analyses of the contents of ovarian cysts.

1. A thick, viscid fluid of this nature, obtained from a woman aged 40 years, had an alkaline reaction, a specific gravity of 1022, and when allowed to stand, deposited a sediment composed of granules, inflammatory globules, and minute nucleated cells.

In 1000 parts there were:

Water	-	-	-	952-2
Solid constituents	-	-	-	47-8
Protein-compounds thrown down	by alcohol	-	-	33-6
Extractive matters				9-1
Salts	-	-	-	5-3

consisting chiefly (nearly)
4-08) of chlorides of sodium

On a subsequent occasion (about two months afterwards) the fluid contained:

Water	-	-	-	-	-	-	940-90
Solid constituents	-	-	-	-	-	-	59-10
Albumen precipitable by boiling, after the addition of acetic acid	-	-	-	-	-	-	42-62
Extractive matters	-	-	-	-	-	-	12-03
Inorganic constituents	-	-	-	-	-	-	5-58

2. In another instance a fluid was obtained containing:

Water	-	-	-	-	867-57
Solid constituents	-	-	-	-	132-43
Mucin with exudation-cells	-	-	-	-	27-65
Albumen coagulated by boiling	-	-	-	-	55-70
Albuminate of soda	-	-	-	-	39-26
Fat	-	-	-	-	4-70
Alcohol-extract	-	-	-	-	3-52
Water-extract	-	-	-	-	2-35
Fixed salts	-	-	-	-	7-81

The mucin and exudation-cells were precipitated from the fluid by acetic acid; they were then boiled with alcohol in order to remove any adherent fat, and submitted to ultimate analysis.

'They yielded:

Carbon	-	-	-	55.443	A little more nitrogen and hydrogen, and rather less oxygen than protein.
Hydrogen	-	-	-	7.114	
Nitrogen	-	-	-	18.305	
Oxygen	-	-	-	19.138	

In the following analyses, 1 and 2 represent the composition of the contents of two other cysts in the same ovary, 3 represents the fluid in another case:

		1.	2.	3.
Water	-	903-11	839-904	799-85
Solid constituents	-	96-89	160-096	200-15
Albumen	-	40-38		—
Albuminate of soda	-	36-50	150-534	172-95
Fat	-	3-40	—	3-13
Extractive matters	-	6-07	1-456	14-50
Salts	-	8-54	8-006	10-43

Valentin has analyzed a tumour (*meliceris*) containing a fluid of the consistence of honey, of a dirty yellow colour, devoid of odour, and leaving on evaporation, 11.3% of solid residue, which consisted of, in 100 parts:

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Coagulated albumen	-	-	-	-	53-49
Olein and oleate of soda	-	-	-	-	28-50
Cholesterin	-	-	-	-	3-12
Stearin	-	-	-	-	1-96
Uncoagulated albumen with a little potash	-	-	-	-	9-17
Lime	-	-	-	-	1-88
Magnesia	-	-	-	-	0-92

[The contents of a strumous cyst analyzed by Scherer contained:

Water	-	-	-	-	920-54
Solid constituents	-	-	-	-	79-46
Albumen with a little blood	-	-	-	-	61-23
Extractive matters	-	-	-	-	8-71 } Transformed matters
Fat (chiefly cholesterin)	-	-	-	-	1-80 } 10-51
Salts	-	-	-	-	7-72]

Fluid of pemphigus. I have examined the faintly yellow fluid occurring in the bullæ of pemphigus. It had an acid reaction, and deposited a sediment of corpuscles resembling mucus- or pus-corpuscles in form, and in which a nucleus was very apparent. Its specific gravity was 1018. On evaporation it developed an acid odour similar to that which is observed on evaporating the saliva in cases of ptyalism and due to the presence of a little acetic acid. When submitted to a high temperature it deposited a quantity of very white albumen: the acid reaction was then more powerful than before, but after evaporation to dryness, it disappeared, for the alcohol with which the residue was extracted had scarcely a perceptibly acid reaction. It was composed of:

Analysis 168.					
Water	-	-	-	-	940-0
Solid constituents	-	-	-	-	60-0
Fat containing cholesterin	-	-	-	-	2-6
Albumen with earthy phosphates	-	-	-	-	48-0
Extractive matter soluble in alcohol, with lactate of soda }	-	-	-	-	65
and chlorides of sodium and potassium	-	-	-	-	
A substance resembling ptyalin, soluble in water	-	-	-	-	1-9
Free acetic acid and mucus-corpuscles	-	-	-	-	imponderable

Five years afterwards I examined the fluid from the same patient during a fresh attack. In its physical characters it was much as before.

It contained in 1000 parts:

Analysis 169.					
Water	-	-	-	-	959-8
Solid constituents	-	-	-	-	40-2
Albumen with mucus-corpuscles	-	-	-	-	28-1
Fat	-	-	-	-	3-0
Alcohol-extract	-	-	-	-	3-0
Fixed salts	-	-	-	-	4-5

The fluid was strongly acid from the presence of acetic acid; no indications of urea were detected.

[Girardin has recently made an analysis of the fluid in certain vesicles on the abdomen.

In 1000 parts there were contained:

Water	-	-	-	-	939-500
Solid constituents	-	-	-	-	60-500
Albumen	-	-	-	-	49-200

Cholesterin	- - - - -	6475
Alcohol-extract	- - - - -	1075
Phosphates of soda and lime, and chloride of sodium	- - - - -	3750]

Fluid of hygroma. I have examined the fluid of an hygroma situated on the lower jaw of a horse. The fluid was almost clear and transparent, but so extremely viscid that it could be drawn out into long threads. Its reaction was alkaline. Under the microscope a few very large mucus-corpuscles, three or four times the ordinary size, could be observed, occurring as round granular vesicles, in which, in consequence of the opacity of the investing membrane, the nucleus could not be detected.

The fluid did not mix with water, but a separation of white flocculi took place; white gelatinous flocculi were likewise precipitated by alcohol. Ebullition rendered the fluid opaque, but did not altogether coagulate it.

The gelatinous mass precipitated by alcohol was boiled in spirit of .848 and then warmed with water, in which it swelled and became viscid without dissolving. On the addition of acetic or hydrochloric acid to the swollen mass it coagulated immediately into opaque fibrils. It was perfectly soluble in a dilute solution of caustic potash with the aid of heat, and again precipitable by acetic acid, without being soluble in an excess of the reagent. Hydrochloric acid threw down a substance which was immediately redissolved, and a peculiar odour of sulphuretted hydrogen was evolved, just as when we add hydrochloric acid to an alkaline solution in which horn-shavings have been digested.

The hydrochloric-acid solution was scarcely rendered at all turbid by ferrocyanide of potassium, but was strongly precipitated by tannin. From these experiments it appeared that the substance under examination was mucin. Alcohol took up a very small quantity of chloride of sodium and lactate of soda from this fluid. The mucin left, on incineration, an ash of phosphate of lime.

Dropsical fluids. The fluids that collect in different parts of the body, especially in the cavities of the abdomen and thorax, and in the subcutaneous cellular tissue, in a certain class of disorders (dropsies,) have been frequently submitted to chemical analysis. Fluids of this nature are usually of a faint yellow colour, and more or less turbid; flocculi of coagulated fibrin are sometimes present, and occasionally, after acute inflammatory attacks, they contain so large an amount of that constituent as to assume a gelatinous consistence. Their specific gravity varies from 1010 to 1020 or higher; their reaction is alkaline, and they sometimes contain so small a quantity of albumen as only to be rendered slightly turbid by heating, while in other cases the amount is so large that the whole fluid becomes coagulated; the quantity of salts, especially of chloride of sodium, is frequently also considerable. If the kidneys are affected, urea is generally present. The fat usually contains cholesterin.

The following analyses of the fluid found in the brain in cases of hydrocephalus approximate closely in their results:

	Berzelius.	Mulder.	Marchand.	
			1.	2.
Water	968-30	969-97	966-54	969-93
Solid constituents	-	11-70	10-003	13-46
Albumen	-	1-66	0-549	1-10
Fat	-	-	0-070	0-05
Alcohol-extract with lactate of soda	-	2-32	2-538	2-10
Water-extract	-	0-26	-	0-13
Chlorides of sodium and potassium	-	7-09	6-553	7-87
Earthy phosphates	-	0-09	0-090	0-10
Sulphate of soda	-	-	0-146	-
Carbonate of soda	-	-	0-057	0-11
Soda	-	0-28	-	-

Marcet obtained similar results in his analyses of dropsical fluids. Marchand found an extraordinarily large amount of urea in the fluid, removed by tapping, from a woman with ascites.

There were contained in 1000 parts:

Water	-	-	-	-	-	952-8
Solid constituents	-	-	-	-	-	47-6
Albumen	-	-	-	-	-	23-6
Urea	-	-	-	-	-	4-2
Chloride of sodium	-	-	-	-	-	8-1
Carbonate of soda	-	-	-	-	-	2-1
Phosphate and traces of sulphate of soda	-	-	-	-	-	0-6
A viscous substance	-	-	-	-	-	8-9

[Several analyses of the fluid of ascites have been recently made, some of which we shall insert in a condensed form. The two following were made by Scherer:

1. A whitish turbid fluid removed from the abdomen by paracentesis, in a case of dropsy dependent on abscesses proceeding to chronic suppuration, yielded in 1000 parts:

Water	-	-	-	-	-	966-71
Solid residue	-	-	-	-	-	13-29
Minute granules and soluble albumen	-	-	-	-	-	3-61
Extractive matters	-	-	-	-	-	1-80
Salts	-	-	-	-	-	7-90

The fluid evolved no odour, and was neutral.

2. The fluid obtained by tapping a patient with dropsy from 'steatoma hepatis, carcinoma ventriculi, et perienteritis chronica,' was examined on two occasions:

		1.	2.
Water	-	952-99	960-49
Solid constituents	-	47-01	39-51
Fibrin	-	0-32	-
Albumen	-	11-88	-
Albuminate of soda	-	22-70	29-73
Extractive matters	-	3-03	2-12
Fat	-	1-26	1-63
Salts	-	7-22	5-94

Urea was sought for in analysis 1, but without success.

Heller analyzed the dropsical effusion in the case of ascites noticed in p. 531.

The fluid had a milky appearance, was neutral, devoid of odour, and its specific gravity was 1007.

¹ Of this, 0-21 was cholesterol.

Nitric acid and heat scarcely affected it, but an enormous precipitate was thrown down by nitrate of silver.

In 1000 parts there were contained:

Water	-	-	-	-	-	950-00
Solid constituents	-	-	-	-	-	50-00
Extractive matters and traces of albumen	-	-	-	-	-	5-97
Fat	-	-	-	-	-	0-84
Fixed salts (almost exclusively chloride of sodium)	-	-	-	-	-	44-00

Not a trace of urea or of bile-pigment could be detected. The fat was perfectly saponifiable and contained no cholesterin. In addition to the enormous amount of chloride of sodium in the effusion, it was abundant in the urine (see page 532,) and the sweat was so saturated with it that it crystallized in minute glittering particles on the skin.

In a case of Bright's disease, in which the walls of the abdomen were punctured, a fluid with an alkaline reaction and specific gravity 1007.5 was obtained. It was analyzed by Heller, and found to contain:

Water	-	-	-	-	-	980-640
Solid constituents	-	-	-	-	-	19-360
Albumen	-	-	-	-	-	8-121
Free fat	-	-	-	-	-	0-220
A soda-soap	-	-	-	-	-	0-392
Extractive matters	-	-	-	-	-	2-546
Fixed salts	-	-	-	-	-	8-080

It yielded no indications of urea, bile-pigment, or cholesterin.

Percy found in a fluid of this nature:

Water	-	-	-	-	-	952-0
Solid constituents	-	-	-	-	-	48-0
Albumen	-	-	-	-	-	38-0
Indeterminate organic matter	-	-	-	-	-	3-2
Salts	-	-	-	-	-	7-6

I made an analysis of the dropsical fluid obtained by puncturing the abdomen of a young man in whom the subsequent autopsy revealed suppuration of both kidneys. Urea was present in this fluid, which was of a faintly yellow colour, strongly alkaline, and threw down flocculi of albumen on boiling.

It contained:

						Analysis 170.
Specific gravity	-	-	-	-	-	1010
Water	-	-	-	-	-	978-0
Solid constituents	-	-	-	-	-	120
Fat containing cholesterin	-	-	-	-	-	10
Albumen	-	-	-	-	-	84
Alcohol-extract	-	-	-	-	-	0-3
Spirit-extract	-	-	-	-	-	1-7
Carbonate of soda and phosphate of lime	-	-	-	-	-	1-2
Chloride of sodium and lactate of soda	-	-	-	-	-	68
Urea	-	-	-	-	-	1-2

Thoracic effusions. I have analyzed the fluid obtained from the cavity of the pleura by paracentesis thoracis. It was of a yellow colour, devoid of odour, and consisted of two portions, viz., a thin liquid portion and a gelatinous clot floating on it. The fluid had a strongly alkaline reaction, a specific gravity of 1022-4, and showed,

under the microscope, a few primary cells of the size of pus or mucus-corpuscles. The coagulum was slight in its consistence, and when examined microscopically was found to exhibit the structure of coagulated fibrin, with a few enclosed primary cells; when washed with water the fibrin was left perfectly white.

In 1000 parts there were contained:

						Anal. 171.
Water	:	:	:	:	:	934.72
Solid constituents	:	:	:	:	:	63.98
Fibrin	:	:	:	:	:	1.02
Fat	:	:	:	:	:	1.05
Alcohol-extract with salts	:	:	:	:	:	1.35
Spirit-extract with salts	:	:	:	:	:	10.64
Albuminate of soda	:	:	:	:	:	17.66
Albumen	:	:	:	:	:	31.00
Fixed salts	:	:	:	:	:	9.50

The fluid, both in its physical and chemical characters, closely resembled lymph.

[The following analyses of similar fluids have been made by Scherer. In 1 and 2 the fluid was taken at an interval of eight days from the same person. In 3, it should be observed, that the fluid was not analyzed till a fortnight after the operation.

		1.	2.	3.
Water	:	935.52	936.06	938.0
Solid constituents	:	64.48	63.94	72.0
Fibrin	:	0.62	0.60	—
Albuminate of soda	:	49.77	52.78	—
Albumen	:	—	—	52.0
Fat	:	2.14	1.35	2.4
Alcohol-extract	:	1.64	—	5.2
Water-extract	:	1.62	1.61	9.2
Salts	:	7.93	7.40	10.2

I once analyzed the fluid obtained from incisions in the lower extremities of a man with Bright's disease. It contained a very appreciable amount of urea, and a considerable quantity of albumen, with much chloride of sodium.

I give the results of this analysis:

		Analysis 172.
Specific gravity	:	1012
Water	:	976.0
Solid constituents	:	24.0
Fat containing cholesterol	:	0.5
Albumen	:	7.0
Alcohol-extract with urea	:	2.0
Spirit-extract	:	1.9
Water-extract	:	3.0
Carbonate of soda and phosphate of lime	:	1.0
Chloride of sodium and lactate of soda	:	8.1

[Heller has recently published an elaborate essay on the chemistry of the fluids in Bright's disease, including several analyses of the subcutaneous serum. His analyses of the blood and urine will be found in Appendix II.

a. The subcutaneous serum from the body of a man who died from Bright's disease was of a pale yellow colour, alkaline, and had a specific gravity of 1011. It contained only a very small quantity

of albumen, but a large amount of fixed salts, viz. 10·1 in 1000 parts of the fluid.

b. Several ounces of fluid were obtained by incisions in the leg of a man aged 40 years, with general oedema. The liquid was clear and almost as colourless as water, there being merely a very faint tint of yellow. On cooling there was formed at the bottom of the vessel a very light and delicate clot, which was slightly pink from the presence of a few blood-corpuscles; the serum was then entirely colourless, had an alkaline reaction and specific gravity of 1010.

In 1000 parts there were:

Clot	:	:	:	:	:	:	1978
Serum	:	:	:	:	:	:	981·22

And there were contained in the fluid:

Water	:	:	:	:	:	:	986·800
Solid constituents	:	:	:	:	:	:	13·200
Fibrin	:	:	:	:	:	:	0·134
Extractive matter, an imponderable quantity of } albumen, and urea	:	:	:	:	:	4·226	
Fixed salts	:	:	:	:	:	:	8·840

c. The serous fluid obtained in another case, by incisions in the leg, was turbid, of a dirty yellow colour, and deposited a flocculent sediment, consisting for the most part of epithelium-scales, with a little pus and a few crystals of ammoniaco-magnesian phosphate. The reaction was strongly alkaline, and the specific gravity 1010.

There were contained in 1000 parts:

Water	:	:	:	:	:	:	975·20
Solid constituents	:	:	:	:	:	:	24·80
Albumen	:	:	:	:	:	:	5·42
Extractive matters, salts, free and saponified fat, and urea	:	:	:	:	:	3·76	
Fixed salts	:	:	:	:	:	:	15·62

We shall revert to this subject, in relation to the composition of the blood and urine, in the Appendix.]

I have analyzed the fluid obtained from a hydrocele; it was remarkable for the large amount of cholesterin contained in it; it was of a yellow colour, devoid of odour, alkaline, and sparkled when shaken, in consequence of the numberless crystals of cholesterin suspended in it. The amount of solid constituents was larger than I ever observed in any other serous fluid of a similar nature. The amount of salts, composed principally of chloride of sodium, is also very remarkable.

This fluid contained:

		Analysis 173.
Water	:	860·00
Solid constituents	:	140·00
Cholesterin with a little margarin and oleic acid	:	8·40
Albumen	:	48·30
Albuminate of soda with extractive matter	:	6·88
Extractive matter soluble in alcohol	:	2·30
Chlorides of sodium and calcium, a little sulphate, and traces } of phosphate of lime	:	72·52
Phosphate of lime with traces of peroxide of iron	:	0·70

[Heller has recently published an essay on the fluid of hydrocele, founded on three analyses:

1. Nearly ten ounces of fluid were removed from a man aged 65 years, who had laboured under hydrocele for seven years.

The fluid was of a dark-brown colour, alkaline, and of specific gravity 1021.

It contained a large amount of bile-pigment, but no cholesterin, and after standing deposited a sediment.

In 1000 parts there were contained :

Water	-	-	-	-	-	919.2
Solid constituents	-	-	-	-	-	80.8
Albumen	-	-	-	-	-	58.0
Free fat	-	-	-	-	-	1.6
A soda-soap, biliphein, haemato-globulin, dissolved haematin, and extractive matters	-	-	-	-	{	13.9
Fixed salts	-	-	-	-	-	7.3

2. About three ounces were obtained from a man aged 30 years. The fluid was of a clear yellow colour, strongly alkaline, and had a specific gravity of 1020.

It contained in 1000 parts:

Water	-	-	-	-	-	934.00
Solid constituents	-	-	-	-	-	66.00
Albumen	-	-	-	-	-	59.61
Fixed salts, chiefly chloride of sodium	-	-	-	-	-	7.68
Fat, but no cholesterin	-	-	-	-	-	0.14
Water-extract	-	-	-	-	-	1.17
A soda soap, biliary resin and pigment, urea, uric acid, and alcohol extract	-	-	-	-	{	4.20

3. One ounce was taken from a man aged 50 years. It was clear, of a dark yellow colour, alkaline, and had a specific gravity of 1020.

It contained in 1000 parts:

Water	-	-	-	-	-	906.36
Solid constituents	-	-	-	-	-	93.64
Albumen	-	-	-	-	-	60.00
Fat containing cholesterin	-	-	-	-	-	0.23
Extractive matters, biliphein, and a soda-soap	-	-	-	-	{	24.04
Fixed salts, chiefly chloride of sodium	-	-	-	-	-	9.37

A specimen examined by Percy contained in 1000 parts :

Water	-	-	-	-	-	927.4
Solid constituents	-	-	-	-	-	72.6
Albumen	-	-	-	-	-	59.2
Fat taken up by ether	-	-	-	-	-	a trace
Alcohol-extract	-	-	-	-	-	1.2
Water-extract	-	-	-	-	-	2.2
Chloride of sodium with traces of chloride of potassium	-	-	-	-	-	6.0
Soda and lime, with sulphuric, phosphoric, and carbonic acids	-	-	-	-	{	4.0]

A matter obtained from the scrotum in another case of hydrocele was of a brown colour, hardly fluid, but rather of a pulpy consistence. Under the microscope¹ it was found to contain an immense number of crystals of cholesterin, numerous blood and pus-corpuscles,

¹ [According to Heller, on making a microscopic examination of the fluid of hydrocele, we may expect to find: 1, blood-corpuscles; 2, fragments of epithelium; 3, coagula of albumen or fibrin; 4, fat; 5, cholesterin; 6, globules of inflammation; 7, pus; and 8, occasionally spermatozoa.]

and a yellow substance resembling coagulated albumen. On heating, it coagulated like blood; it yielded a large amount of cholesterin to ether, and of haemato-globulin to hot spirit.

[The following analyses by Scherer, of fluid effusions found in the body after death, are worthy of notice.

1. The fluid found in the abdominal cavity after death from scirrhus degeneration of the chylopoietic viscera, contained:—

Water	-	-	-	-	-	963-39
Solid constituents	-	-	-	-	-	36-61
Albumen	-	-	-	-	-	12-69
Albuminate of soda and hematin	-	-	-	-	-	7-13
Alcohol-extract	-	-	-	-	-	3-98
Water-extract	-	-	-	-	-	3-72
Fat	-	-	-	-	-	0-34
Salts	-	-	-	-	-	858

The fluid was slightly bloody, and on standing deposited a yellow sediment.

2. In a case of metro-peritonitis and broncho-pneumonia there was found in the abdomen a reddish-yellow fluid which developed a little sulphuretted hydrogen, had a well-marked acid reaction from the presence of free lactic acid, and coagulated perfectly on heating. The fluid separated from the coagulum by filtration had an acid reaction, was of a yellow colour, and contained much extractive matter in solution. On warming it with carbonate of zinc, filtering, and evaporating, crystals of lactate of zinc were readily obtained.

In 1000 parts there were contained:

Water	-	-	-	-	909-83
Solid residue	-	-	-	-	90-17
Cells	-	-	-	-	12-95
Albumen	-	-	-	-	36-00
A substance resembling pyin	-	-	-	-	8-96
Fat and alcohol-extract	-	-	-	-	14-105
Free lactic acid	-	-	-	-	1-05
Ammonia salts and water-extract	-	-	-	-	9-30
Fixed salts	-	-	-	-	8-88

The exudation in the pleural sac was of a blood-red colour, although no blood-corpuscles could be detected by the microscope. It was strongly acid.

In 1000 parts there were contained:

Water	-	-	-	-	936-718
Solid residue	-	-	-	-	63-283
Albumen	-	-	-	-	31-746
Fat and extractive matter	-	-	-	-	26-503
Free lactic acid	-	-	-	-	1-610
Fixed salts	-	-	-	-	7-110

3. In another case of metro-peritonitis the fluid in the abdominal cavity was of a yellowish-gray colour, neutral, and coagulated freely on heating.

In 1000 parts there were contained:

Water	-	-	-	-	909-79
Solid constituents	-	-	-	-	90-91
Albumen	-	-	-	-	48-17

FLUID PRODUCTS.

Alcohol-extract	-	-	-	14.16	
Fat	-	-	-	1.97	
Water-extract	-	-	-	6.80	
A substance thrown down by acetic acid	-	-	-	9.90	
Fixed salts	-	-	-	9.00	

4. In a similar case, the abdominal exudation separated in a short time into a purulent deposit, and a reddish-yellow supernatant fluid. The microscope revealed the presence of cells, organisms resembling minute algae, granules, and nuclei. The exudation had a faintly acid reaction and developed a considerable quantity of sulphuretted hydrogen.

In 1000 parts there were contained :

Water	-	-	-	902.70	
Solid constituents	-	-	-	97.30	
Pus- and exudation-corpuscles	-	-	-	13.61	
Albumen precipitable by water	-	-	-	12.98	
Albumen coagulated by boiling	-	-	-	23.84	
A substance thrown down by acetic acid and not soluble in an excess	-	-	-	12.41	
Alcohol-extract	-	-	-	14.96	
Water-extract	-	-	-	5.36	
Fat	-	-	-	6.20	
Fixed salts	-	-	-	8.63	

5. A similar fluid in a case of 'metritis septica' was strongly acid, and contained in 1000 parts:

Water	-	-	-	905.74	
Solid constituents	-	-	-	94.26	
Pus- and exudation-cells	-	-	-	14.67	
Coagulable albumen	-	-	-	32.46	
Fat	-	-	-	6.91	
Lactic acid	-	-	-	1.50	
A substance precipitable by acetic acid	-	-	-	10.42	
Alcohol-extract	-	-	-	12.60	
Water-extract	-	-	-	7.45	
Fixed salts	-	-	-	9.38	

6. The abdominal exudation in a case of metro-peritonitis and endo-metritis differed from the preceding fluids in not depositing a purulent sediment, but after standing for a considerable time remained turbid and of a yellowish-red colour. Under the microscope there were seen free granules and nuclei, together with exudation globules filled with granular contents. It was strongly alkaline.

In 1000 parts there were contained :

Water	-	-	-	966.10	
Solid constituents	-	-	-	33.90	
Albuminate of soda	-	-	-	18.72	
Fat	-	-	-	1.35	
Extractive matters	-	-	-	6.12	
Salts	-	-	-	8.73	

7. In a case of 'perimetritis, metritis, and endometritis,' the microscopic characters of the fluid were similar to those in the preceding case. The exudation was neutral. When boiled it coagulated and deposited flocculi; the filtered liquid was rendered turbid by acetic acid, and the turbidity did not disappear on the addition of an excess of the test. The fluid was, however, rendered clear by the

addition of hydrochloric acid. These reactions show that the precipitated substance was not casein, but pyin.

In 1000 parts there were contained:

Water	-	-	-	941.27	
Solid constituents	-	-	-	58.73	
Albumen	-	-	-	25.21	Unchanged protein
Pyin	-	-	-	4.37	
Fat	-	-	-	2.32	Metamorphosed tissue
Alcohol-extract	-	-	-	12.27	
Water-extract	-	-	-	8.11	
Fixed salts	-	-	-	7.93	

8. We shall conclude this series of cases with a notice of the analysis of the fluid found in the peritoneum of a boy aged 8 years, who died from perienteritis. The exudation deposited a sediment similar to those described as forming in the preceding cases of puerperal fever; it was neutral and coagulated on boiling.

It contained in 1000 parts:

Water	-	-	-	-	980.00	
Solid constituents	-	-	-	-	20.00	
Albumen	-	-	-	-	6.49	
Pyin	-	-	-	-	2.45	
Extractive matters	-	-	-	-	4.74	
Salts	-	-	-	-	6.32]	



APPENDIX I.

NOTE 1. Ultimate composition of protein. (Mulder.)

	Vegetable albumen.	Fibrin.	Albumen.	Atoms.	Calculated.
Carbon	-	54.99	55.44	55.30	40 55.20
Hydrogen	-	6.87	6.95	6.94	31 7.00
Nitrogen	-	15.66	16.05	16.03	5 16.01
Oxygen	-	22.48	21.56	21.74	12 21.70

Liebig's formula $C_{55}H_{68}N_5O_{21}$ is founded on a series of analyses by Scherer, and gives C 55.742, H 6.827, N 16.143, O 21.228.

NOTE 2. Ultimate composition of tritoxide of protein. (Mulder.)

	1.	2.	3.	4.	Atoms.	Calculated.
Carbon	-	51.47	51.60	51.38	51.48	40 51.45
Hydrogen	-	6.60	6.64	6.78	6.56	32 6.72
Nitrogen	-	15.37	15.09	15.01	-	5 14.90
Oxygen	-	26.56	26.58	26.82	-	16 26.93

1, was prepared from chloride of protein, of which the chlorine had been removed by ammonia; 2, by boiling fibrin in water; 3, by boiling albumen in water; and 4, from an inflammatory crust.

NOTE 3. Ultimate composition of binoxide of protein.

	1.	2.	3.	Atoms.	Calculated.
Carbon	-	53.69	53.64	53.44	40 53.36
Hydrogen	-	6.90	6.88	7.04	31 6.75
Nitrogen	-	15.63	15.85	14.51	5 15.45
Oxygen	-	23.71	23.64	25.01	14 24.44

1, was obtained by boiling fibrin in water; it then remains behind insoluble; 2, is the albuminose of Bouchardat (Comptes Rendus, 20 Juin, 1842.) Von Baumhauer, in Scheikund. Onderzoek. Deel 1, p. 568; 3 was obtained from hair (see p. 20.) These analyses were made in Mulder's laboratory.

NOTE 4. Ultimate composition of erythroprotid. (Mulder.)

	1.	2.	3.	Atoms.	Calculated.
Carbon	-	-	-	56.63	13 56.12
Hydrogen	-	-	-	5.93	8 5.64
Nitrogen	-	-	-	10.23	1 10.00
Oxygen	-	-	-	27.21	5 28.24

NOTE 5. Ultimate composition of leucin. (Mulder.)

	1.	2.	3.	Atoms.	Calculated.
Carbon	-	-	-	55.64	12 55.79
Hydrogen	-	-	-	9.30	12 9.11
Nitrogen	-	-	-	10.51	1 10.77
Oxygen	-	-	-	24.55	4 24.33

NOTE 6. Ultimate composition of protid. (Mulder.)

	1.	2.	3.	Atoms.	Calculated.
Carbon	-	-	-	59.20	13 59.04
Hydrogen	-	-	-	6.62	9 6.67
Nitrogen	-	-	-	10.56	1 10.62
Oxygen	-	-	-	23.62	4 23.77

NOTE 7. Ultimate composition of albumen of the blood. (Mulder.)

					Atoms.	Calculated.
Carbon	-	-	-	-	54-84	400
Hydrogen	-	-	-	-	7-09	310
Nitrogen	-	-	-	-	15-83	50
Oxygen	-	-	-	-	21-23	120
Phosphorus	-	-	-	-	0-33	1
Sulphur	-	-	-	-	0-68	2

In a few instances (see pp. 13, 14, 141, &c.) I find that I have doubled the equivalent of phosphorus. Adopting this notation in p. 26, the formula, instead of being $10\text{Pr} + \text{S}_2\text{P}$, would become $10\text{Pr} + \text{S}_2\text{Pr}_2$.

Albumen of eggs differs from the above in containing only half the amount of sulphur. Mulder's analysis gave:

					Atoms.	Calculated.
Carbon	-	-	-	-	54-48	400
Hydrogen	-	-	-	-	7-01	310
Nitrogen	-	-	-	-	15-70	50
Oxygen	-	-	-	-	29-00	120
Phosphorus	-	-	-	-	0-43	1
Sulphur	-	-	-	-	0-38	1

NOTE 8. Ultimate composition of fibrin from ox-blood. (Mulder.)

					Atoms.	Calculated.
Carbon	-	-	-	-	54-56	400
Hydrogen	-	-	-	-	6-90	310
Nitrogen	-	-	-	-	15-72	50
Oxygen	-	-	-	-	29-13	120
Phosphorus	-	-	-	-	0-33	1
Sulphur	-	-	-	-	0-36	1

Hence, in its composition, it is identical with the albumen of eggs.

NOTE 9. Ultimate composition of casein from cows' milk. (Mulder.)

					Atoms.	Calculated.
Carbon	-	-	-	-	54-96	400
Hydrogen	-	-	-	-	7-15	310
Nitrogen	-	-	-	-	15-80	50
Oxygen	-	-	-	-	21-73	120
Sulphur	-	-	-	-	0-36	1

NOTE 10. Ultimate composition of crystallin from the eye. (Mulder.)

Carbon	-	-	-	55-39
Hydrogen	-	-	-	6-94
Nitrogen	-	-	-	16-51 hence it closely resembles casein.
Oxygen	-	-	-	20-91
Sulphur	-	-	-	0-25

NOTE 11. Ultimate composition of globulin.

The analysis referred to in the text was published by Mulder in the 'Bulletin' for 1839. In his recent work on the 'Chemistry of Animal and Vegetable Physiology,' he states that, although a protein-compound, its real composition is not yet known.

NOTE 12. Ultimate composition of pepsin. (Vogel.)

Carbon	-	-	-	-	57-718
Hydrogen	-	-	-	-	5-666
Nitrogen	-	-	-	-	21-088
Oxygen	-	-	-	-	16-064

NOTE 13. Ultimate composition of chondrin. (Scherer.)

		Cartilage of the ribs of a calf.	Cornea.	Atoms.	Calculated.
Carbon	-	49-496	50-895	49-523	48
Hydrogen	-	7-133	6-962	7-097	40
Nitrogen	-	14-908	14-908	14-399	6
Oxygen	-	28-463	27-235	28-983	20

Mulder obtained from costal cartilage:

					Atoms.	Calculated.
Carbon	-	.	.	.	9.96	49.93
Hydrogen	-	.	.	.	6.63	6.61
Nitrogen	-	.	.	.	14.44	14.47
Oxygen	-	.	.	.	28.59	28.58
Sulphur	-	.	.	.	0.38	0.41

NOTE 14. Ultimate composition of glutin. (Mulder.)

Glutin from hartshorn. Glutin from isinglass. Atoms. Calculated.

		1.	2.			
Carbon	-	50.05	50.05	50.76	13	50.37
Hydrogen	-	6.48	6.64	6.64	10	6.33
Nitrogen	-	18.35	18.39	18.31	2	17.95
Oxygen	-	25.12	24.92	24.29	5	25.35

NOTE 15. Ultimate composition of glycicoll or gelatin sugar. (Mulder.)

				Atoms.	Calculated.
Carbon	-	.	.	34.27	8
Hydrogen	-	.	.	6.51	6.32
Nitrogen	-	.	.	19.84	2
Oxygen	-	.	.	39.38	7

NOTE 16. Ultimate composition of haematin. (Mulder.)

		1.	2.	3.	Atoms.	Calculated.
Carbon	-	.	66.49	66.20	65.73	44
Hydrogen	-	.	5.30	5.44	5.28	5.37
Nitrogen	-	.	10.54	10.46	10.57	3
Oxygen	-	.	11.01	11.15	11.97	6
Iron	-	.	6.66	6.75	6.45	1

1 and 2 were prepared from arterial and 3 from venous ox-blood.

NOTE 17. Ultimate composition of cholic acid. (Dumas.)

			Atoms.	Calculated.
Carbon	-	.	68.5	42
Hydrogen	-	.	9.7	36
Oxygen	-	.	21.6	21.6

NOTE 18. Ultimate composition of urea.

	Prout.	Liebig and Wohler.	Atoms.	Calculated.
Carbon	-	19.99	20.02	2
Hydrogen	-	6.65	6.71	4
Nitrogen	-	46.65	46.73	2
Oxygen	-	26.63	26.54	3

NOTE 19. Ultimate composition of uric acid.

	Prout.	Mitscherlich.	Liebig and Wohler.	Atoms.	Calculated.
Carbon	-	39.975	35.62	5	36.00
Hydrogen	-	2.225	2.38	2	2.36
Nitrogen	-	31.125	34.60	2	33.37
Oxygen	-	26.775	27.20	3	26.27

NOTE 20. Ultimate composition of hippuric acid.

The hydrated acid contains:

	Mitscherlich.	Liebig.	Dumas.	Atoms.	Calculated.
Carbon	-	60.63	60.742	18	60.9
Hydrogen	-	4.98	4.969	9	4.9
Nitrogen	-	7.90	7.816	1	7.8
Oxygen	-	26.49	26.483	6	26.4

NOTE 21. Ultimate composition of uric oxide.
(Liebig and Wöhler.)

					Atoms.	Calculated.
Carbon	:	:	:	:	39-28	5
Hydrogen	:	:	:	:	2-95	2
Nitrogen	:	:	:	:	36-35	2
Oxygen	:	:	:	:	21-42	2

NOTE 22. Ultimate composition of cystin.

	Prout.	Thaullow.	Atoms.	Calculated.
Carbon	29-675	30-01	6	30-31
Hydrogen	5-125	5-10	6	4-94
Nitrogen	11-650	11-60	1	11-70
Oxygen }	53-150	{ 28-38 25-51	4 2	26-47 26-48
Sulphur }				

NOTE 23. Ultimate composition of glycerin. (Pelouze.)

	Hydrated.	Atoms.	Anhydrous.	Atoms.
Carbon	39-59	6	43-44	6
Hydrogen	8-61	8	8-35	7
Oxygen	51-80	6	47-84	5

NOTE 24. Ultimate composition of stearic acid. (Redtenbacher.)

	Atoms.	Calculated.
Carbon	76-71	68
Hydrogen	12-86	68
Oxygen	10-46	7

Ultimate composition of margaric acid. (Redtenbacher.)

	Atoms.	Calculated.
Carbon	75-64	34
Hydrogen	12-86	35
Oxygen	11-50	4

The former contains two, and the latter one atom of water.

NOTE 25. Ultimate composition of lactic acid.

Lactic acid has been analyzed by several chemists, who have all arrived at nearly the same results.

	Hydrated.	Atoms.	Anhydrous.	Atoms.
Carbon	40-46	6	44-92	6
Hydrogen	6-61	6	6-55	5
Oxygen	52-93	6	48-53	5

Note.—In p. 185, it was inadvertently stated that hippuric acid is non-nitrogenous. The object of the author is to show that, compared with uric acid, it contains very little nitrogen.

APPENDIX II.

ADDITIONS.

PAGE 220. *Blood in thoracic inflammation.* Zimmermann¹ has communicated several observations respecting the blood in inflammatory affections of the respiratory organs. The following are the results of his analyses, conducted according to the method of Andral and Gavarret:

	Water.	Fibrin.	Blood-corpuses.	Res. of serum.
1.	790-0	3-0	127-0	80-0
2.	784-0	4-0	126-0	86-0
	796-0	6-0	119-0	79-0
3.	810-0	7-0	106-0	77-0
	805-0	5-0	103-5	85-5
4.	806-0	9-6	109-9	74-5
	774-0	4-0	142-0	80-0
5.	781-0	4-0	137-0	78-0
	786-0	4-0	131-5	78-5
6.	796-0	3-0	128-0	73-0
7.	794-0	3-0	123-5	79-5
8.	792-0	3-0	120-0	89-0
9.	800-0	4-0	119-5	76-5
10.	800-0	4-0	108-0	88-0
11.	798-0	7-0	116-0	79-0
	815-0	8-0	100-5	76-5
12.	806-0	3-5	100-5	90-0

If we compare the mean of these analyses with the average deduced by Andral and Gavarret from 58 analyses of the blood in similar cases, we have:

Zimmermann	796-2	4-75	118-10	80-85
Andral	799-0	7-30	114-10	81-00

The leading difference in these averages occurs in the fibrin. Zimmermann suggests that probably Andral and Gavarret used only buffed blood.

PAGE 247. *Blood in intermittent fever.* In four cases in which the blood of persons residing in malarious districts, who were suffering from intermittent fever, was analyzed by Cozzi, the fibrin occurred in its normal quantity, but the fat and albumen were diminished. In three of these cases there was a great excess of cholesterol, and scarcely any phosphates; in the remaining case (No. 3) these salts were abundant, while no cholesterol was found.

The following are the results of Cozzi's analyses:

¹ Zur Analysis und Synthesis der pseudo-plastischen Prozesse, pp. 1841-99.

	1.	2.	3.	4.
Water and salts	737.67	705.49	732.45	809.17
Fibrin	2.40	2.06	2.29
Fat15	.21	.13
Albumen	48.71	56.61	47.59
Blood-corpuscles	211.27	235.63	217.54

The blood in (1) was taken from a soldier with severe intermit-tent fever, accompanied with considerable enlargement of the spleen and liver.

The blood in (2) was taken from a man with a quartan fever, whose spleen and liver were much enlarged, and the latter the seat of excruciating pain.

The blood in (3) was taken from an artilleryman, who for five years had been stationed in a malarious district. It was a case of intermit-tent fever, with slight enlargement of the liver, but extraordi-nary hypertrophy of the spleen.

The blood in (4) was taken from a man with angina tonsillaris, who had suffered from fever for a long time: spleen enlarged and very painful.

In addition to the excess of cholesterol in the majority of these cases, bile-pigment was observed in the blood. The connexion be-tween the occurrence of these constituents and the deranged state of the portal system is sufficiently obvious.

PAGE 249. *Blood in certain diseases of the eye.* Zimmermann has published the following analyses of the blood in a peculiar form of endemic ophthalmia recently prevalent at Berlin.

1. In a case of ophthalmia of two days' standing, accompanied with much chemosis, the specific gravity of the blood was 1051. The specific gravity of the serum was 1027, and the clot 1086.

In 1000 parts there were:

Water	-	-	-	-	798.0
Solid constituents	-	-	-	-	2020
Fibrin	-	-	-	-	20
Blood-corpuscles	-	-	-	-	117.5
Solid residue of serum	-	-	-	-	89.5

The serum was of a bluish-red colour and opaque.

2. The blood drawn from a patient on the third day of the oph-thalmia had a specific gravity of 1052. The specific gravity of the serum was 1028, and of the clot, 1090.

In 1000 parts there were:

Water	-	-	-	-	795.0
Solid residue	-	-	-	-	206.0
Fibrin	-	-	-	-	2.0
Blood-corpuscles	-	-	-	-	115.1
Solid residue of serum	-	-	-	-	87.9

3. A patient on the second day of the disease yielded blood of specific gravity 1055. The specific gravity of the serum was 1030, and of the clot 1092.

In 1000 parts there were contained:

Water	:	:	:	:	790
Solid residue	:	:	:	:	210
Fibrin	:	:	:	:	3
Blood-corpuscles	:	:	:	:	115
Solid residue of serum	:	:	:	:	93

4. In similar cases the blood had a specific gravity of 1054. The specific gravity of the serum was 1035, and of the clot 1088.

In 1000 parts there were contained:—

Water	:	:	:	:	794
Solid constituents	:	:	:	:	206
Fibrin	:	:	:	:	3
Blood-corpuscles	:	:	:	:	105
Solid residue of serum	:	:	:	:	9

5. A soldier with conjunctivitis and scleritis of the right eye. The specific gravity of the blood was 1052. The specific gravity of the serum was 1030, and of the clot 1084.

In 1000 parts there were contained:—

Water	:	:	:	:	795·0
Solid constituents	:	:	:	:	205·0
Fibrin	:	:	:	:	25
Blood-corpuscles	:	:	:	:	104·0
Solid residue of serum	:	:	:	:	98·5

6. In a case of conjunctivitis of both eyes without fever, the specific gravity of the blood was 1055. The specific gravity of the serum was 1036, and of the clot 1088.

In 1000 parts there were contained:—

Water	:	:	:	:	786·0
Solid constituents	:	:	:	:	214·0
Fibrin	:	:	:	:	20
Blood-corpuscles	:	:	:	:	113·5
Solid residue of serum	:	:	:	:	98·5

7. In a case of ophthalmia of the left eye, the specific gravity of the blood was 1055. The specific gravity of the serum was 1031, and of the clot, 1090.

In 1000 parts of blood there were contained:—

Water	:	:	:	:	790·0
Solid constituents	:	:	:	:	210·0
Fibrin	:	:	:	:	20
Blood-corpuscles	:	:	:	:	114·7
Solid residue of serum	:	:	:	:	93·3

Three days having elapsed, venesection was again ordered. The specific gravity of the blood was then 1050·8. The specific gravity of the serum was 1027·7, and of the clot 1078.

In 1000 parts there were contained:—

Water	:	:	:	:	802·0
Solid constituents	:	:	:	:	198·0
Fibrin	:	:	:	:	20
Blood-corpuscles	:	:	:	:	116·2
Solid residue of serum	:	:	:	:	89·8

8. The blood of a soldier on the third day of the disease had a specific gravity of 1052. The specific gravity of the serum was 1031, and of the clot 1080.

In 1000 parts there were contained:

Water	-	-	-	796-0
Solid constituents	-	-	-	204-0
Fibrin	-	-	-	3-5
Blood-corpuscles	-	-	-	106-7
Solid residue of serum	-	-	-	93-8

Four days afterwards the specific gravity was 1050-5. The specific gravity of the serum was 1028, and of the clot 1078.

In 1000 parts there were contained:

Water	-	-	-	800
Solid constituents	-	-	-	200
Fibrin	-	-	-	2
Blood-corpuscles	-	-	-	108
Solid residue of serum	-	-	-	90

After an interval of ten days he was again bled. The specific gravity was 1050. The specific gravity of the serum was 1027, and of the clot 1078.

In 1000 parts there were contained:

Water	-	-	-	804-0
Solid constituents	-	-	-	196-0
Fibrin	-	-	-	3-5
Blood-corpuscles	-	-	-	97-0
Solid residue of serum	-	-	-	95-5

A glance at the leading characters of the blood in these eight cases, will show, that in these patients it was in a state of hypnosis.

PAGE 253. *Blood in scrofula.* The blood in this form of disease has been analyzed by Mr. Nicholson.¹

The analyses were conducted on Andral and Gavarret's method:—

	Water.	Fibrin.	Blood-corpuscles.	Resid. of serum.
1.	816-5	3-0	101-0	79-5
2.	820-2	2-8	98-0	79-0
3.	820-5	2-4	98-0	79-1
4.	821-0	3-0	97-0	79-0
5.	823-0	2-5	96-5	78-0
6.	830-0	2-3	80-0	78-7
7.	843-0	2-0	79-0	79-0
8.	839-0	2-0	79-0	80-0
9.	855-3	1-2	63-5	80-0
10.	855-2	1-8	64-0	79-0
11.	854-3	1-7	65-5	78-5
12.	855-0	2-0	64-0	79-0

The blood-corpuscles were few, light coloured, and irregular, and there was sometimes an appearance as if their circumference was notched and divided.

PAGE 265. *Blood in Bright's disease.* In a case of albuminuria, in which the dropsy was only of a fortnight's standing, the blood was analyzed by Dr. Ayres.² There was a firm buffy coat on the blood, a quarter of an inch in thickness.

The coagulum itself was very firm, and so bulky as almost to fill the glass.

There were contained in 1000 parts:

¹ Northern Journal of Medicine, Nov. 1845.

² Lancet, Aug. 2, 1845.

Water	-	-	-	-	765.022
Solid constituents	-	-	-	-	234.978
Fibrin and tritoxide of protein	-	-	-	-	11.450
Fat	-	-	-	-	a trace
Albumen	-	-	-	-	65.875
Hæmato-globulin	-	-	-	-	138.185
Albuminate of soda and salts	-	-	-	-	13.940
Osmosome	-	-	-	-	1.510

No urea could be detected in this blood, the leading characters of which were a great increase of fibrin and a diminution of the water and fat.

The following analyses have been recently published by Heller.¹

1st Case.—A man of tolerably robust appearance, aged 38 years. The disease was somewhat advanced, and there was considerable oedema. The blood was analyzed on two occasions. On the first occasion it was taken by cupping from the region of the kidney. It was very fluid but of the normal colour. The clot was small and presented no peculiarity. The serum was slightly coloured. Under the microscope the blood-corpuscles appeared large and swollen. The blood was tested for urea, and found to contain a considerable quantity.

Five ounces were subsequently removed by venesection. The colour of the blood on this occasion was rather dark, and the coagulation was perfect. The clot was of a bright red colour on the surface, but otherwise dark, and there was no buffy coat. The serum was very pale and opalescent, and its specific gravity was only 1022. It contained no bile-pigment, and its reaction was strongly alkaline.

In 1000 parts were contained:

Water	-	-	805.39	
Solid constituents	-	-	194.61	
Fibrin	-	-	3.52	
Albumen	-	-	51.45	
Fixed salts	-	-	6.70	
Extractive matter	-	-	8.15	Solid residue of serum 69.15
Urea	-	-	1.85	
Hæmato-globulin	-	-	122.94	

2d Case.—A woman, aged about 30 years, with the disease in an early stage. There was slight oedema of the feet and face, accompanied with pain in the region of the kidneys. Four ounces of blood taken from the arm presented no physical peculiarities. The specific gravity of the serum was only 1018, or 10° lighter than the normal serum. The clot was to the serum in the ratio of 544.75 : 455.25.

In 1000 parts of blood there were contained:

Water	-	-	-	-	816.04	
Solid constituents	-	-	-	-	183.96	
Fibrin	-	-	-	-	2.66	
Albumen with a little extractive matter	-	-	-	-	48.03	
Fixed salts	-	-	-	-	6.96	Solid residue of serum.
Urea	-	-	-	-	1.74	56.73
Hæmato-globulin	-	-	-	-	124.57	

Heller's general conclusions respecting the blood in Bright's disease are, that the specific gravity and the amount of solid consti-

¹ Archiv für Physiologische und Pathologische Chemie und Mikroskopie, vol. ii. p. 173.

tuents are diminished, and that the diminution is dependent alone on the increase of the albumen, which, for the most part, is found in the urine, but to a less degree also in the dropsical effusions. The appearance of the blood is normal, and in its coagulation it presents no peculiarity. The serum is pale, of low specific gravity (as may be shown by the common urinometer,) and contains no bile-pigment.

The fibrin and blood-corpuscles occur in the ordinary quantity. The solid residue of the serum is much diminished in consequence of the great decrease of the albumen. Urea is abundant in the blood; in the first analysis it amounted to 1.85 in 1000 parts: reckoning the whole amount of blood in the body at thirty pounds, this would contain about an ounce of urea. The presence of urea in the blood must not, however, be regarded as peculiar to Bright's disease, since it has been found in a large quantity in cholera, ischuria, and other diseases associated with suppression of urine.

The fixed salts present no remarkable deviation from the normal standard, but are usually slightly below the healthy average.

PAGE 276. *Menstrual fluid.* Since the publication of the text, an analysis of this secretion has been made by Dr. Letheby.¹ The menses were retained by an imperforate hymen, which, when cut into, permitted the escape of about forty ounces of a thick and almost black fluid, having the appearance of treacle. When examined under the microscope, with a power of 300, it was found to be quite free from fibrin, but numerous corpuscles were observed floating in it. The greater number of them were altered blood-corpuscles, but there were also noticed the exudation or inflammatory globules (of Gerber and Gluge,) lymph-corpuscles, mucus-corpuscles, epithelium-scales, and minute granules resembling mere dots.

The fluid had an alkaline reaction, and was perfectly miscible with water; when heated a little below 212°, it formed a firm coagulum.

It was analyzed in accordance with Simon's directions, and was found to contain:

Water	:	:	:	:	:	:	857.4
Solid constituents	:	:	:	:	:	:	142.6
Fat	:	:	:	:	:	:	5.3
Albumen	:	:	:	:	:	:	69.4
Globulin	:	:	:	:	:	:	49.1
Hematin	:	:	:	:	:	:	2.9
Salts	:	:	:	:	:	:	8.0
Extractive matters	:	:	:	:	:	:	6.7

Another analysis was formed, with the view of estimating the quantity of mucus, blood-corpuscles, and soluble albumen, and gave the following results:

Water	:	:	:	:	:	:	857.4
Solid matters insoluble in cold water, and consisting of mucus,							29.6
lymph, and exudation globules with epithelium							
Solid matters soluble in cold water, and consisting of saponified							53.8
fats and blood-corpuscles							
Albumen	:	:	:	:	:	:	52.7
Salts	:	:	:	:	:	:	7.0

¹ Lancet, Aug. 2, 1845.

These must be taken as the constituents of the fluid. It can, however, hardly be regarded as the normal menstrual secretion; from the length of time in which it remained in the vagina it became mixed with an excess of mucus, and, acting as an irritant, produced the inflammatory globules that were observed in it.

PAGE 301. *Saliva.* Lassaigne has instituted a series of experiments in reference to the animal diastase of Mialhe. The results of these experiments are as follow:

a. Human saliva, and that of the horse, at the temperature of 103°, exert no solvent power on starch, which remains quite unaltered in its physical and chemical properties.

b. At a higher temperature (158° to 167°) maintained for three hours and a half, horse's saliva acts on starch exactly as water does; that is to say, the granules become tumid and distended, without being changed into either dextrine or glucose.

c. Human saliva obtained from the mouth has no action on starch at the temperature of the body; but converts it rapidly into dextrine at a temperature between 158° and 167°, and subsequently converts the dextrine into glucose.

d. During the digestion of raw amyloseous substances, the saliva, being at the temperature of the animal body, cannot exert the influence attributed to it by Mialhe; it can merely, as most of the older and modern physiologists maintain, contribute to moisten the alimentary bolus, and dissolve such of its principles as are soluble in water.

PAGE 303. *Morbid saliva.* Scherer has analyzed the saliva of a girl aged 15 years, suffering from a scorbutic affection of the mouth. There was copious ptyalism, the saliva amounting to about 40 ounces in twenty-four hours. The secretion was very liquid, fetid, and alkaline. The specific gravity was 1004.

In 1000 parts there were contained:

Water	-	-	-	-	-	-	988.8
Solid constituents	-	-	-	-	-	-	11.2
A caseous-like substance precipitable by acetic acid	-	-	-	-	-	-	6.5
Fat taken up by ether	-	-	-	-	-	-	0.6
Extractive matter and ptyalin	-	-	-	-	-	-	1.8
Carbonate of soda	-	-	-	-	-	-	1.2
Chloride of sodium	-	-	-	-	-	-	0.7
Phosphate of lime	-	-	-	-	-	-	0.4

On examining with the microscope the fluid immediately after its discharge, there was found in it a large number of infusoria, and a peculiar conervoid-like vegetation.

PAGE 305. *Fluid of ranula.* Dr. Gorup-Besanez¹ has published an elaborate paper on this subject, in which, after discussing at considerable length the question whether the tumour constituting ranula arises from an obstruction of Wharton's duct, and contains retained and modified saliva, or whether it is a species of ordinary cystic

¹ Heller's Archiv für Phys. und Patholog. Chemie und Mikroskopie, vol. ii. p. 22.

tumour, he arrives at the latter conclusion. In 100 parts of fluid he found:

Water	-	-	-	-	-	96.029
Solid constituents	-	-	-	-	-	4.971
Alcohol-extract, traces of fat, and chloride of sodium	-	-	-	-	-	1.063
Water-extract (gluten?)	-	-	-	-	-	0.923
Albuminate of soda	-	-	-	-	-	2.986

The microscope detected in the fluid some blood-corpuscles and globules which were at least twice as large as the corpuscles of mucus or saliva, and resembled Gluge's inflammatory globules.

Hence the liquid differed entirely, both chemically and microscopically, from saliva.

PAGE 310. *The bile.* Frerichs¹ has recently analyzed bile both in health and disease. He gives the following as the physical characters of healthy human bile.

In colour it is always deep brown, but, when seen in thin layers, it has a brownish-yellow tint. It is very fluid, being viscid only in new-born infants. The specific gravity varies from 1032 to 1040. On examining with the microscope bile from the gall-bladder, with which, of course, a certain amount of mucus is mixed, there are observed:—1. Transparent or grayish round vesicles, about 1-700th of a line in diameter. They disappear on the addition of alcohol or ether, and are removed by filtration. 2. Conical yellow bodies, about 1-140th of a line in length, and about 1-300th or 1-400th of a line in breadth, apparently devoid of nuclei; these are epithelium-cells from the gall-bladder. 3. Here and there irregular dark granules, which disappear on the addition of a solution of potash, apparently pigment cells. 4. Occasionally minute crystals of cholesterin, occurring as colourless rhombic tablets. The chemical characters are shown in the two following analyses. The bile in these cases was obtained from healthy men, killed by severe accidents.

			^{1.}	^{2.}
Water	-	-	86.00	85.92
Solid constituents	-	-	14.00	14.08
Bilate of soda	-	-	10.23	9.14
Cholesterin	-	-	0.16	0.26
Margarin and olein	-	-	0.32	0.92
Mucus	-	-	2.66	2.98
Chloride of sodium	-	-	0.25	0.20
Tribasic phosphate of soda	-	-	0.20	0.25
Basic phosphate of lime " magnesia }	-	-	0.18	0.28
Sulphate of lime	-	-	0.02	0.04
Peroxide of iron	-	-	traces	traces

PAGE 312. *Morbid bile.* Frerichs has published the two following analyses of morbid bile:

		Bile in pneumonia.	Bile in chronic meningitis.
Water	-	94.60	95.98
Solid constituents	-	5.40	4.02
Bilate of soda	-	4.16	2.63
Fat	-	0.42	0.20
Mucus and salts	-	1.00	1.21

¹ Hannov. Annal. 1 and 2, 1845.

PAGE 315. For further information on the use of the bile we must refer the reader to the recent work of Platner, "Ueber die Natur und den Nutzen der Galle," Heidelberg, 1845. A summary of his views on this subject is given in Müller's Archiv, No. 4, 1845.

PAGE 320. *Gastric juice.* Dr. R. D. Thompson has published an account of a series of experiments made with the view to determine the acid or acids occurring in the gastric juice. In order to prevent complication of the phenomena, the animals were fed on vegetable food alone. His experiments tend to show that no free hydrochloric acid is present in the stomach of animals living on vegetable food, but that the free acid is the lactic. A little acetic acid was also generally present. A full account of his experiments may be seen in the "London Medical Gazette," October, 1845, or in the "Half-yearly Abstract of the Medical Sciences," vol. ii., pp. 347-51.

PAGE 326. *Vicarious secretion of milk.* A singular case of this nature is recorded in p. 63. During the last summer the following case has been published. Professor Cannobio¹ received five or six ounces of a liquid that flowed from an abscess in the thigh of a woman who was suckling. In appearance it resembled whey, but was somewhat whiter. It was homogeneous, and, after remaining in a bottle for thirty-five hours, threw down no sediment. Its specific gravity was 1010. It remained alkaline for seven days, and then became slightly acid. On the addition of a few drops of acetic acid, it became slightly turbid, but there was no sensible deposit until the expiration of the second day.

On analyzing the fluid according to Haidlen's directions, it was found to contain in 1000 parts:

Water	-	-	-	-	-	982-64
Solid constituents	-	-	-	-	-	17-36
Butter with traces of cholesterol	-	-	-	-	-	2-77
Sugar of milk, soluble salts, and alcohol-extract	-	-	-	-	-	7-29
Casein and insoluble salts	-	-	-	-	-	6-25
Fragments of linseed from poultices, &c.	-	-	-	-	-	1-06

PAGE 340. The reader would do well to consult Dr. Davy's paper on "the colostrum of the cow," in the Medico-Chirurg. Transactions, 1845.

PAGE 345. *Bitches' milk.* Dumas² has recently published some analyses of the milk of bitches, the object of his paper being to show that, after they have been restricted for some time to a purely animal diet, all traces of sugar disappear from the milk. A bitch fed on bread, meat, bone, and fat, yielded milk containing:

Water	-	-	-	-	-	69-80
Solid constituents	-	-	-	-	-	30-20
Butter	-	-	-	-	-	12-40
Extractive matter	-	-	-	-	-	2-50
Casein	-	-	-	-	-	13-60
Soluble salts	-	-	-	-	-	0-71
Insoluble salts	-	-	-	-	-	0-77

¹ Journal de Pharmacie, Août, 1845.

² Annales des Sciences Nat., Sept. 1845.

The sugar in this instance crystallized on the surface of the extractive matter.

After feeding, for the space of a fortnight, on horseflesh alone, the milk yielded:

Water	-	-	-	-	-	77.14
Solid constituents	-	-	-	-	-	22.86
Butter	-	-	-	-	-	7.93
Casem	-	-	-	-	-	11.16
Extractive matter	-	-	-	-	-	3.89
Soluble salts	-	-	-	-	-	0.45
Insoluble salts	-	-	-	-	-	0.57

Not a trace of sugar could be detected in the latter specimen. His other analyses are merely confirmatory of the same fact.

Dumas believes that the milk-globules are surrounded by a caseous investment; he found that if milk be shaken with pure ether, the two liquids which are at first mixed, separate on standing, and the milk preserves its ordinary appearance, whilst the ether dissolves scarcely any thing. If, however, acetic acid is added to the milk, and the mixture is boiled, the whole of the butter may be removed by subsequent agitation with ether, and the milk ceases to be opalescent.

PAGE 385. *Colouring matters of urine.* Heller has recently published some observations on certain new colouring matters in the urine. He believes that there exists a yellow pigment (uroxanthin) which occurs in solution in very small proportion in healthy urine, but is much increased in certain forms of disease. It possesses the property of being converted by oxidation (either spontaneously or artificially) into two other pigments, one of which is of a ruby-red tint, (urrrhodin,) while the other is of the colour of ultramarine, (uroglauclin.)

These are both insoluble in the urine, and being deposited, form a purple or violet-coloured sediment.

That uroxanthin and its products are derived from urea seems probable from the circumstance that uroglauclin and urrrhodin occur in diseases different in most of their characters, but similar in one—the presence of an excess of urea in the blood: thus they are found in Bright's disease, in cholera, and in suppression of urine. Further, when these products occur in considerable quantity, (especially when the blue sediment is spontaneously formed,) there is always much carbonate of ammonia, and very little urea (perhaps mere traces) in the urine, as is often the case in Bright's disease. Finally, Heller has observed the blue tint developed by nitrate of urea artificially prepared and kept moist, and has likewise produced it by adding nitric acid to an old solution of urea partially converted into carbonate of ammonia.

The existence of a large quantity of uroxanthin in urine is indicated:

1. By the clear light-yellow colour of the urine when that secretion is acid, as in cholera, and sometimes in Bright's disease.
2. By the presence of the products of its oxidation, uroglauclin

and urrhodin, which either of themselves form a violet-coloured sediment, or communicate that tint to a sediment already formed.

On allowing urine abounding in uroxanthin to stand for some time, it is observed that after the formation of the sediment has ceased, the fluid from the surface downwards assumes a violet tint, and this change of colour takes place with a rapidity proportional to the amount of carbonate of ammonia produced by the decomposition of urea.

Hence, on keeping such urine in a high cylindrical glass, three distinct strata are observed; lowermost, a violet sediment; in the middle, yellow and nearly clear urine; and superiorly, a violet or purple turbid layer.

On shaking the glass, the whole urine assumes a bluish-green tint, because the urrhodin, formed principally at the surface, becomes converted, by agitation with a full supply of atmospheric air, into uroglauuin which, mixing with the central yellow layer of urine, develops a green tint. The uroglauuin thus formed ultimately settles as a blue powder on the sides and at the bottom of the vessel. Hence there is obviously no fixed proportion between the qualities of uroglauuin and urrhodin.

3. If much uroxanthin is present, the crystals of uric acid (separated either spontaneously or by the addition of an acid) have a beautiful blue or amethyst tint.

4. Lastly, if much uroxanthin is present, it may be recognised by the addition of concentrated nitric acid, (ten drops to half an ounce of urine,) which at once communicates a brilliant violet colour to the fluid: if a smaller amount is present, the change of colour is developed more slowly.

The nitric acid oxydizes the uroxanthin, and converts it into uroglauuin and urrhodin. Sulphuric and hydrochloric acids act similarly, but with less activity. If albumen is present in urine treated in this manner, it is either precipitated blue at once, or assumes that tint gradually, according to the amount of uroxanthin. This is constantly noticed in Bright's disease on treating urine abounding in uroxanthin with an acid, and allowing it to stand for a couple of days; uroglauuin separates in dark blue crystalline groups, visible to the naked eye, partly on the surface and partly at the bottom of the vessel. On taking a drop from the surface and examining it under the microscope, uroglauuin is seen in the form represented in Plate iii., fig. 97.

To separate the two products of oxidation of uroxanthin, we collect on a filter the sediment thrown down by nitric acid, and agitate it with cold spirit of 830, which takes up the urrhodin (as also does ether;) the residue is boiled for some time with spirit of the same strength, until the fluid becomes somewhat concentrated; we thus get a bright blue solution of uroglauuin.

To exhibit these substances in normal urine, the fluid must be so far evaporated as just to remain liquid. On adding concentrated

nitric acid to the cold residue, a crystalline magma of nitrate of urea is at once formed; on adding to this a few more drops of nitric acid (and sometimes even this is unnecessary) it assumes a violet tint. If the crystalline mass is allowed to stand for some time, and is then dissolved in the smallest possible quantity of distilled water, after being left at rest for some time, it deposits a sediment in which urrhodin and uroglauclin may be detected either by the microscope or by extraction with cold and then with boiling spirit.

The action of nitrate of silver on uroxanthin is very singular. On precipitating the chlorine by an excess of nitrate of silver, from urine acidulated with nitric acid, and then carefully neutralizing the filtered liquid by ammonia, there is not only a pale yellow precipitate of phosphate of silver, but the fluid assumes a brown tint, and in a short time there is likewise a brown sediment.

Heller has not yet succeeded in isolating uroxanthin.

Uroglauclin associated with urrhodin, occurs in urinary sediments in Bright's disease, and in cases in which urine, abundant in uroxanthin, has become alkaline in the bladder. Heller has noticed it in these sediments forming groups of delicate prisms. (See Plate iii., figs. 37 and 38 *a*.) It likewise assumes this form when urine, abounding in uroxanthin, is treated with nitric, sulphuric, or hydrochloric acid. In this case it is principally found on the surface of the fluid.

When allowed to crystallize from its cold spirituous solution, it forms groups which appear nearly black, but are blue and transparent at the edges. (See Plate iii., fig. 38 *a, b.*)

Urrhodin appears to be a less oxydized product of uroxanthin than uroglauclin, and usually occurs in much larger quantity. It is most commonly observed in cases in which the urine is alkaline before emission, in consequence of containing much vesical mucus, and its development in such cases is hastened by the addition of nitric acid. The method of isolating it has been already described. Heller has never succeeded in obtaining it from its spirituous solution in a crystalline form. It occurs in granules, which, under the microscope, appear of a beautiful rose colour. It is resinous in its nature, and burns with a clear flame.

Heller concludes his paper (of which the above is but a brief abstract) with a notice of some experiments on uroerythrin, the ordinary pigment of inflammatory urine.

On treating uric-acid crystals obtained from healthy urine with cold alcohol, the pigment formed a carmine solution, and the uric acid remained comparatively devoid of colour, being of a yellowish-brown tint from the brown pigment of the urine. The spirituous carmine solution on exposure to the air gradually became purple, and had all the properties of uroglauclin, previous to which it appeared to be identical with urrhodin.

On treating the red sediment common in inflammatory affections and tinged with uroerythrin, with hot and cold alcohol and ether,

the red pigment remained unaffected, unless a little acid was added. The difference of solubility in the above menstrua is therefore sufficient to separate uroerythrin from urrhodin.

Heller's theory of the production of uroglaucin and urrhodin affords a satisfactory explanation of the occurrence of the blue sediments noticed in pp. 502, 543.

PAGE 397. *Quantitative determination of urea.* Two papers on this subject have appeared almost simultaneously during the last three months—one by Ragsky, the other by Heintz.

With regard to the quantitative determination of urea, Ragsky¹ observes there is this great objection to its separation either as a nitrate or oxalate, that both those salts are perceptibly soluble, which prevents on the one hand their complete precipitation, and on the other hand their perfect washing, on which latter account they retain a certain amount of extractive matter. No other compound of urea being known, adapted for its quantitative determination, Ragsky endeavoured to apply the products of its decomposition to this purpose. After several experiments made to this effect, with chlorine and with nitrous acid, he found that concentrated sulphuric acid answers the purpose best. For this purpose, a mixture of one part of urea, with from three to four parts of concentrated sulphuric acid is introduced into a flask, and exposed to the heat of a sand-bath, which must not exceed 572° to avoid loss of ammonia. The decomposition of urea commences at 383° and the evolution of carbonic-acid gas is very lively at 392°. In this process one equivalent of urea assumes the elements of two equivalents of water, and transposing with the latter is converted into two equivalents of carbonic acid which escape as gas, and two equivalents of ammonia which remain in combination with the sulphuric acid.



He determined, in this manner, accurately-weighed portions of pure urea dried at 212 degrees, and determined the ammonia subsequently in the form of ammonio-chloride of platinum. The following numbers will show how approximately urea may be determined in this way.

1. 0·2612 grammes of urea yielded 1·9323 grammes of ammonio-chloride of platinum corresponding to 0·2598 grammes of urea.²

2. 0·3139 grammes of urea yielded 2·3175 grammes of ammonio-chloride of platinum, corresponding to 0·3116 grammes of urea.

3. 0·2716 grammes of urea yielded 2·0400 grammes of ammonio-chloride of platinum, corresponding to 0·2743 grammes of urea.

To ascertain how far the presence of extraneous matters might interfere with the accuracy of the results, sugar was mixed with the urea, but the results were unaffected. The next point was to ascertain whether the extractive matter would yield ammonia under these

¹ Liebig and Wöhler's Annalen, Oct. 1845.

² The English reader will see the accuracy of the result more clearly by reducing the grammes to grains. From 4·022 grains used in the experiment, 4·001 were recovered.

conditions. For this purpose Ragsky precipitated 120 grammes (nearly 4 ounces) of fresh and healthy urina sanguinis, with acetate of lead, after having previously separated the uric acid by means of some hydrochloric acid. The precipitate was mixed with water, decomposed by sulphuretted hydrogen, and the yellow fluid thus produced evaporated to a syrup, and charred with sulphuric acid. The charred mass was subsequently extracted with water, the solution evaporated, and finally treated with alcohol and bichloride of platinum. This process gave no indication of the presence of ammonia. Having thus ascertained that the extractive matters, which are normally present in urine, exercise no adverse influence on the quantitative determination of urea by means of sulphuric acid and bichloride of platinum, he next proceeded to determine by this method the amount of urea present in divers samples of urine, in order to compare the results with those obtained by the ordinary methods. He found after several experiments, that 7 grammes (a little more than five drachms) of urine required about 3·5 grammes (or half the weight) of concentrated sulphuric acid. If less of the acid be taken the charred mass will readily dry up, and some loss of ammonia will be incurred in consequence. The mixture of urine and sulphuric acid is kept in a moderate state of ebullition, there is a great evaporation of water, and the fluid turns black. The temperature rises higher and higher, until at about 39° there ensues evolution of carbonic acid gas in small bubbles. The cessation of the disengagement of gas indicates that the urea present in the analyzed urine is completely decomposed. The black residue is then thoroughly extracted with water and the solution filtered. The clear and urine-yellow filtrate is finally evaporated in the water-bath, and the sulphate of ammonia treated with alcohol and bichloride of platinum.

Since urine contains salts of potash and ammonia, which will of course likewise precipitate upon the addition of bichloride of platinum, it is necessary to determine the exact proportion in which these salts are present in the urine under examination. For this purpose a separate weighed portion of urine is precipitated with bichloride of platinum, and the amount of precipitate subtracted from the former.

Two samples of urine of 7 grammes each, treated according to this method, yielded 0·202 grammes of urea, or 2·88%, and 0·199 grammes of urea or 2·84%. Fourteen grammes of the same urine was treated according to the ordinary plan; they yielded 0·617 grammes of nitrate of urea, or 2·15% of urea. The extractive matters of the urine yielded no ammonia.

These experiments prove that the method of determining urea in the form of ammonio-bichloride of platinum yields much more accurate results than the plan usually adopted; it may, therefore, in many cases be advantageously employed, with this precaution, that all substances likely to interfere with the accuracy of the process (as uric and hippuric acids, albumen, &c.) be previously removed. It

might be advisable in certain cases to separate the urea in the first place by means of oxalic acid, and then to decompose the oxalate with sulphuric acid.

The following table may save trouble in calculation.

1 atom of ammonio-chloride of platinum corresponds to	0·134498 of urea.
2 "	" " " " 0·268996 "
3 "	" " " " 0·403494 "
4 "	" " " " 0·537992 "
5 "	" " " " 0·672490 "
6 "	" " " " 0·806988 "
7 "	" " " " 0·941484 "
8 "	" " " " 1·075984 "
9 "	" " " " 1·210482 "

The author concludes his paper by an acknowledgment of the kind assistance of Liebig.

In principle the method adopted by Heintz¹ is so similar to the above, that it is unnecessary to enter into the details. Both writers agree respecting the inaccuracy of the ordinary method.

PAGE 475. *Urine in Bright's disease.* In Heller's memoir already referred to, we find the following analyses of the urine in this disease.

a. In the case noticed in p. 683, of the man aged 38 years, the urinary secretion was much diminished. The urine was turbid, of a dark yellow colour, very acid, of specific gravity 1017, and deposited a slight, finely flocculent sediment consisting of albuminous fungi, pavement epithelium, the peculiar cylindrical forms observed in Bright's disease, mucus-corpuscles, and a tolerably large number of blood-corpuscles.

On the addition of nitric acid, albumen with a violet tint was precipitated; hence the urine contained a large amount of uroxanthin.²

In 1000 parts there were contained:

Water	-	-	-	-	-	948·0
Solid constituents	-	-	-	-	-	52·0
Urea	-	-	-	-	-	6·1
Uric acid	-	-	-	-	-	no trace
Fixed salts	-	-	-	-	-	3·6
Extractive matters and uroxanthin	-	-	-	-	-	23·9
Albumen with some haemato-globulin	-	-	-	-	-	18·4

The greater part of the salts consisted of sulphate of potash; only slight quantities of chloride of sodium and phosphate of soda were present, and after the removal of the albumen not a trace of earthy phosphates could be detected.

No hippuric acid could be obtained from the urine, and as uric acid was likewise absent, the acidity (which in this case was very marked) could not be dependent on these acids. Heller concludes from various observations that the acid reaction is dependent on the presence of the uroxanthin.

A week afterwards the urine was again analyzed. The secretion was still diminished, was very turbid, of a pale reddish colour, and formed a flocculent reddish sediment. The specific gravity was

¹ Poggendorff's Annalen, No. 7, 1845.

² See page 688.

1010, the reaction acid, and the composition of the fluid nearly the same as when previously examined.

At the expiration of another week, and just before the patient's death, the secretion continued diminished, and the urine rapidly became putrid. The specific gravity was 1011, urea was present in very small quantity, and the sediment contained much pus; in other points the urine remained the same as before.

b. The patient was a man aged 40 years, with considerable œdema of the whole body.

The urinary secretion was much diminished. It was examined on several occasions, principally in reference to the salts.

The urine was of a pale yellow colour, acid, and of specific gravity 1018. There was a slight deposit, consisting of colourless uric-acid crystals, much pavement epithelium, cylinders, albuminous fungi, and a few mucus-corpuscles. The urine contained a large quantity of albumen, very little urea, and only traces of uric acid. The salts amounted to 7·4 in 1000 parts, and contained an excess of sulphates with a diminution of chloride of sodium.

On the following day the organic constituents were similar; the sediment, however, contained in addition some granular cells (the inflammatory globules of Gluge.)

The urine was subsequently analyzed some days afterwards. It presented the same appearance as before, and the deposit was similar. The reaction was acid, and the specific gravity 1017.

In 1000 parts there were contained:—

Water	-	-	-	-	9680
Solid constituents	:	:	:	:	420
Fixed salts	-	-	-	-	94

c. A middle-aged woman with considerable œdema.

The urine was diminished in quantity, was of a dull yellow colour, turbid, faintly acid, and of specific gravity 1017. It deposited a sediment consisting of numerous epithelium scales and cylinders, albuminous fungi, and a few uric-acid crystals. The urine contained a large amount of albumen, which when precipitated by nitric acid had a faintly violet tint, indicating the presence of uroxanthin. The urea, uric acid, and salts were much diminished; the latter amounting to no more than 3 in 1000 parts of urine. Of the various constituents of the saline residue the chloride of sodium was the most diminished.

d. The urine of a patient with considerable œdema, was analyzed. It was of a faint yellow colour, turbid, acid, with a specific gravity of 1006, and deposited a slight sediment of pavement epithelium, cylinders, mucus-corpuscles, albuminous fungi, and a few crystals of uric acid.

In 1000 parts there were contained:—

Water	-	-	-	-	985·2
Solid constituents	:	:	:	:	14·8
Organic matter	-	-	-	-	13·6
Fixed salts	-	-	-	-	1·2 containing hardly a trace of chloride of sodium

e. A patient aged 28 years, who first exhibited symptoms of Bright's disease while in the hospital, in consequence of a broken arm from a fall. The spinal cord likewise appeared somewhat injured by the accident.

The urine was much diminished in quantity, scarcely amounting to twelve ounces in the twenty-four hours; it was of a bluish green (or very deep bottle-green) colour, turbid, and deposited after a short time a flocculent light-blue sediment. After standing for a longer period, a dark blue sediment was gradually thrown down, while the supernatant fluid was yellow.

The surface of the urine was covered with a stiff film of uroglauclin, which presented a beautiful copper-like brilliancy when the light fell on it. With refracted light it appeared of a dark-blue colour, and arranged in stellar groups. The sediment, when examined under the microscope, was found to consist of a great quantity of albuminous fungi and minute crystals of ammoniaco-magnesian phosphate, together with groups of uroglauclin, more or less crystalline in structure, and of a magnificent blue colour: a peculiar modification of pavement epithelium was likewise observed,—oval or nearly circular, with large nuclei and nucleolar corpuscles, frequently arranged in groups; and lastly, cylinders with a little pus.

The reaction of the urine was strongly alkaline, and its specific gravity 1013.

On the addition of nitric acid the urine became of a clear blue colour, and albumen with a violet tint was precipitated, which on standing became of a darker blue, while the supernatant fluid assumed a yellowish hyacinthine colour.

Alcohol slowly added, so as to form a layer on the surface, took up an azure colouring matter. On thoroughly mixing the alcohol with the urine, albumen with a beautiful blue tint was precipitated, while the fluid remained of a hyacinthine colour.

Ammonia communicated a brown colour to the urine.

On the addition of a salt of silver to the acidulated urine there was no precipitation of chloride of silver, but when added to neutralized urine a coffee-coloured tint was developed, indicative of uroxanthin.

On the addition of a salt of baryta there was a slight violet-coloured precipitate of sulphate of baryta.

On evaporating the urine there was left a residue of a dark-blue colour, and bright blue spots were observed on the edges of the capsule. It was washed with water, in order to separate the urea, and then extracted with cold spirit of 0·830, which dissolved the urrhodin, and formed a carmine solution. On boiling the residue with spirit, a solution of uroglauclin was obtained, which, on cooling, formed beautiful ultramarine-blue crystals.

The amount of urea was very small, and there was no uric acid or chloride of sodium; on the other hand, there was a large quantity of carbonate of ammonia, and a moderate amount of albumen. The earthy phosphates, phosphate of soda, and sulphate of potash were

present in very diminished quantities. Uroglaucin and urrhodin were present to a large amount.

The urine passed on the following morning (above two ounces) was submitted to analysis. It had a green colour, turbid, and deposited a sediment which, under the microscope, was found to contain carbonic acid and indeed all the constituents noticed the previous day.

The urine was strongly alkaline, emitting a strong odour. The specific gravity was 1013, and the acid, alcohol, &c., the same as before. There was a small amount of albumen. Uroglauuin and urrhodin were in abundance.

The urine contained in 1000 parts:

Water	-	-	-
Solid constituents	-	-	-
Urea	-	-	-
Uric acid	-	-	-
Fixed salts	-	-	-
Uroglauuin, urrhodin, uroxanthin, extractive matter, and carbonate of ammonia	-	-	-
Albumen	-	-	-

Chloride of sodium was altogether absent; the constituents were present in nearly similar proportions.

Death occurred the same evening, about six hours after that event, nearly two ounces of urine were sent to the laboratory. The secretion had lost its previous colour, becoming citron-yellow tint; it was turbid, and depositing a sediment, composed of all the previous ingesta of uroglauuin. It was acid, and remained so for six hours, although exposed during part of that time to the air. Its specific gravity was 1012.

From the examination of the urine it seems that the changes observed in the urine—namely, the loss of colour, the change from a yellow to a green tint, and the deposition of a white precipitate of albumen, which gradually increased in size and density, and after standing for some time became a solid mass—were due to the action of nitric acid. On the addition of this acid the urine became first of a pale yellow colour, and ultimately of a bright red. After these changes it deposited uroglauuin in the form of a bright powdered ultramarine, but under the microscope it was found to be in a crystalline form. On the surface of this urine there was a thin film of a bright red colour, which was the same coppery film that was noticed on the blue glass. Under the microscope detected crystals of uroglauuin in it. Colloidal albumen, added to the sediment, took up urrhodin, assuming a brownish-red colour.

Hence it seems to follow that the acid urine, which had a yellow colour, contained uroxanthin, and that the action of nitric acid, yielding urrhodin, converted the uroxanthin into uroglauuin.

din in the same manner that it had spontaneously done in the case of the bluish-green specimens. To confirm this opinion a portion of the yellow urine was exposed for a length of time to the action of the atmosphere. The same products were slowly developed which had been rapidly produced by nitric acid. The same red metallic film was produced, the same blue tint gradually developed, and, subsequently, the same blue sediment yielding uroglauuin and urrhodin, while the supernatant fluid became pale.

The urine contained albumen, an extremely small quantity of urea, and not a trace of either uric or hippuric acid. Hence the acid reaction could not depend (as Liebig supposes) on those acids, and Heller believes that "the acid reaction of this urine, and, indeed, of the urine in Bright's disease generally, (where uroxanthin is always present in large quantity,) and most probably of the normal secretion, (at least in part,) is dependent on uroxanthin, which comports itself as an acid, being precipitated by metallic salts."

The body was examined two days after death. A small quantity of urine, amounting to hardly a drachm, was found in the bladder. It had much the same properties as the urine removed by the catheter before death: it had the same acid reaction, and the same yellow colour. It deposited a copious sediment, consisting for the most part of pavement epithelium, and the characteristic cylinders; it likewise contained mucus-corpuscles and oil-globules. The urine contained uroxanthin, but not a trace of uroglauuin or urrhodin, which were, however, subsequently obtained, both by nitric acid and by exposure to the atmosphere.

f. A man under the care of Dr. Seibert. The disease was of considerable standing, and had assumed a chronic form. There was much oedema of the feet, extending to the body, and the secretion of urine was diminished. The urine was of a pale wine-yellow colour, turbid, and threw down a slight deposit consisting of pavement epithelium, cylinder, mucus-corpuscles, and crystals of ammoniaco-magnesian phosphate.

It was faintly alkaline and rapidly developed ammonia; its specific gravity was 1014. Nitric and hydrochloric acids communicated a reddish violet tint to it. After a time albumen with a violet tint was precipitated; hence the urine contained uroxanthin.

In 1000 parts there were contained:

Water	-	-	-	-	-	969-25
Solid constituents	-	-	-	-	-	30-75
Urea	-	-	-	-	-	2-50
Uric acid	-	-	-	-	-	0-60
Albumen	-	-	-	-	-	6-25
Extractive matters, uroxanthin, and carbonate of ammonia	-	-	-	-	-	17-70
Fixed salts	-	-	-	-	-	3-50

The fixed salts consisted for the most part of phosphate of soda; they contained mere traces of chloride of sodium, and a very small amount of earthy phosphates and sulphates.

g. A woman aged 30 years, an analysis of whose blood is given in p. 683.

The urine, on the day on which venesection was performed, was tolerably copious, but had been scanty for some days previously. It was of a faint clay-yellow colour, and threw down a flocculent precipitate consisting of pavement epithelium, very long cylinders, mucus- and pus-corpuscles for the most part containing two distinct nuclei, albuminous fungi, a few fat-globules and blood-corpuscles, and a very few minute crystals of uric acid. The reaction of the urine was strongly acid, and its specific gravity 1017. After the removal of the albumen the specific gravity fell to 1013; there was consequently a considerable quantity of albumen present, and with it a proportionate amount of uroxanthin.

The urea was much diminished.

The uric acid was increased, which is always the case in the early stages, and as long as the disease retains the acute form.

The phosphate of soda and sulphates were apparently unaffected; there were mere traces of earthy phosphates, and chloride of sodium was almost entirely absent.

The urine likewise contained haematin in solution, which communicated a brown tint to the fluid, and especially to the albumen on drying.

On the following day the urine and its sediment presented similar characters. The specific gravity was 1012, and after the removal of the albumen 1010.

In 1000 parts there were contained:

Water	:	:	:	:	:	973-74
Solid constituents	:	:	:	:	:	26-26
Urea	:	:	:	:	:	6-48
Uric acid	:	:	:	:	:	0-70
Albumen	:	:	:	:	:	6-03
Fixed salts	:	:	:	:	:	5-05
Extractive and colouring matter	:	:	:	:	:	8-00

h. A man aged 20 years, who had been for a long time under the care of Dr. Bittner. The disease had assumed the chronic form, and there was great general oedema.

The urine was turbid, of a very pale yellow colour, and deposited a trifling sediment composed for the most part of albuminous fungi, cylinders, and pavement epithelium with a few mucus-corpuscles.

The urine was faintly acid, but in the course of thirty-six hours became alkaline. The specific gravity was 1009. It did not contain much albumen, and only a very little uroxanthin. In 1000 parts there were contained:

Water	:	:	:	:	:	978-5
Solid constituents	:	:	:	:	:	21-5
Urea	:	:	:	:	:	2-5
Uric acid	:	:	:	:	:	traces
Albumen	:	:	:	:	:	4-6
Extractive and colouring matters	:	:	:	:	:	9-4
Fixed salts	:	:	:	:	:	5-0

On a further examination of the salts it was found that the chloride of sodium was extremely diminished.

The urine was examined on two separate occasions, some days later, in relation to the solid constituents generally and to the albumen. There were found:

		1.	2.
Water	-	976.6	978.2
Solid constituents	:	21.4	21.7
Albumen	:	4.5	4.5

Hence in these respects it had remained constant.

Some weeks later, and very shortly before the patient's death, the urine was again examined. It was red from the presence of blood, had a putrid odour, and deposited a sediment, which, in addition to the ordinary constituents, contained numerous blood- and mucus-corpuscles, undoubted pus-globules, and a little uric acid. The reaction was acid, and the specific gravity 1010. A considerable amount of uroxanthin was present.

In 1000 parts there were contained :

Water	-	:	:	:	:	976.23
Solid constituents	:	:	:	:	:	23.77
Urea	-	:	:	:	:	1.76
Uric acid	-	:	:	:	:	0.24
Albumen with a little haemato-globulin	-	:	:	:	:	8.75
Extractive and colouring matters	-	:	:	:	:	8.64
Fixed salts	-	:	:	:	:	4.48

The chloride of sodium was much diminished.

Hence we see that blood occurs in the urine, not only in the early stages but likewise towards the close of the disease. In the former case it arises from congestion, in the latter it is a consequence of incipient dissolution.

i. A woman aged 40 years, with much oedema, under the care of Dr. Sterz.

The urine, in this case, was very remarkable for its extremely high specific gravity, dependent on an enormous amount of albumen. The secretion was very much diminished. The urine was of a clay-yellow colour, turbid, and formed a tolerably abundant sediment, containing numerous cylinders and mucus-corpuscles, together with urate of ammonia. There were also a few granular cells (Gluge's inflammatory globules) and numerous albuminous fungi.

The reaction of the urine was acid. Nitric acid caused a dense coagulation of albumen, which rapidly assumed a violet tint; hence a tolerably large amount of uroxanthin was likewise present. The specific gravity was 1047.

In 1000 parts there were contained :

Water	-	:	:	:	:	860
Solid constituents	:	:	:	:	:	140
Albumen	-	:	:	:	:	57

The urine retained these characters for a considerable time, always holding haematin in solution. It subsequently became less dense, as the disease assumed a chronic character.

k. A girl aged ten years: oedema general and well-marked. The urine was very pale, and of a dirty clay-yellow colour; a little fluid fat

separated on the surface. There was a very slight deposit of epithelium and albuminous fungi. Reaction faintly acid; specific gravity 1005. A small quantity of albumen was present, which, on being precipitated by nitric acid, rapidly assumed a violet tint; on the addition of hydrochloric acid the urine was rendered turbid, and likewise became of a violet colour: a relatively increased quantity of uric acid was thus separated, and the crystals were of a beautiful deep blue tint. Hence, notwithstanding the low specific gravity, the urine contained a large amount of uroxanthin. Of urea there were only traces, and the salts were diminished to an extreme degree; the phosphate of soda—the principal ingredient—being far below the average, the sulphates and chloride of sodium very trifling, while there was a mere trace of earthy phosphates. The subsequent dissection confirmed the accuracy of the diagnosis.

l. An aged man, under the care of Dr. Folwaczny. The urine was extremely turbid, of a dark clay colour, and formed a sediment without itself becoming clear. The sediment was composed of albuminous fungi, numerous cylinders, pavement epithelium, and urate of ammonia. It was upon the presence of the last ingredient that the turbidity was dependent, for on the application of a gentle warmth the fluid became clear. The reaction was strongly acid, and the specific gravity 1029. After the removal of the albumen the specific gravity was only 1017. Hence a large quantity of that constituent was present. On the addition of nitric acid, albumen with a deep violet tint was precipitated; consequently there was much uroxanthin in the urine. The urea was far below the average: the uric acid and urate of ammonia were abundant. The salts collectively were much diminished, but most especially the chloride of sodium.

The subsequent dissection proved the accuracy of the diagnosis.

From these and five additional cases Heller draws the following conclusions.

He divides the disease into three stages, in all of which the urine presents separate and distinctive characters.

The first is the congestive stage, during which the urine is red from dissolved blood or haematin, but at the same time is acid unless neutralized by the presence of very much blood.

In the second—the chronic stage—the urine is pale and of a clay-yellow colour, and frequently resembling whey. In the stage of dissolution which (frequently but not invariably) shortly precedes death, the urine is ammoniacal, develops a putrid odour, and is again bloody. At this stage the dropsical effusions give off an odour resembling that of rotten eggs.

In all three stages the urine is (with occasional exceptions) diminished. The largest amount is passed during the chronic stage, when the oedema frequently diminishes for a short time. During the first and last stages, the daily amount of urine seldom exceeds a few ounces, and blood is often present.

The following are the physical characters of the urine. In the

first stage it is red and turbid, forming either a red or white sediment, according as blood-corpuscles are or are not present. The urine is acid, neutral, or slightly alkaline, and has a low specific gravity.

In the second stage the urine is of a clay-yellow colour and turbid, forming a brown sediment; subsequently the fluid becomes of a paler colour, of very low specific gravity, and deposits a white flocculent sediment; and at this period it exhibits a greater tendency to putrefaction than before.

In the third stage the urine is of a dark red colour, and contains more or less blood; it also deposits a red or reddish-brown sediment containing numerous blood-corpuscles. It is either ammoniacal on emission, or rapidly becomes so, and its specific gravity is higher than in the other stages.

The occurrence of blood in the first and third stages is dependent on totally different causes.

In the congestive stage the constituents of the blood enter the urine by the law of endosmosis, and it is not so much actual blood as serum reddened by haematin in solution that passes over; in the last stages, however, the capillaries are actually corroded by the morbid process, and then the blood-corpuscles likewise find their way freely into the urine. Hence in the latter stage the sediment is always of a reddish-brown tint, while in the former it is often white.

The microscopic appearances are divided by Heller into—1, those of constant occurrence, and 2, those occasionally present.

The constant constituents are:

1. Pavement-epithelium, which is always present, and frequently in the congestive stage forms a copious white sediment.

2. Epithelium from the tubes of Bellini, which usually forms only a slight portion of the sediment in the early stages, although sometimes present in large quantity from the commencement of the disease.

3. Albuminous fungi occurring as a clear dotted granular matter in all fluids containing albumen. When they are very abundant the urine develops a mouldy odour.

4. Mucus-corpuscles.

5. Granular cells (globules of inflammation) are always to be found during the congestive stage.

6. Fat-globules, especially in the chronic form of the disease.

The occasional constituents are:

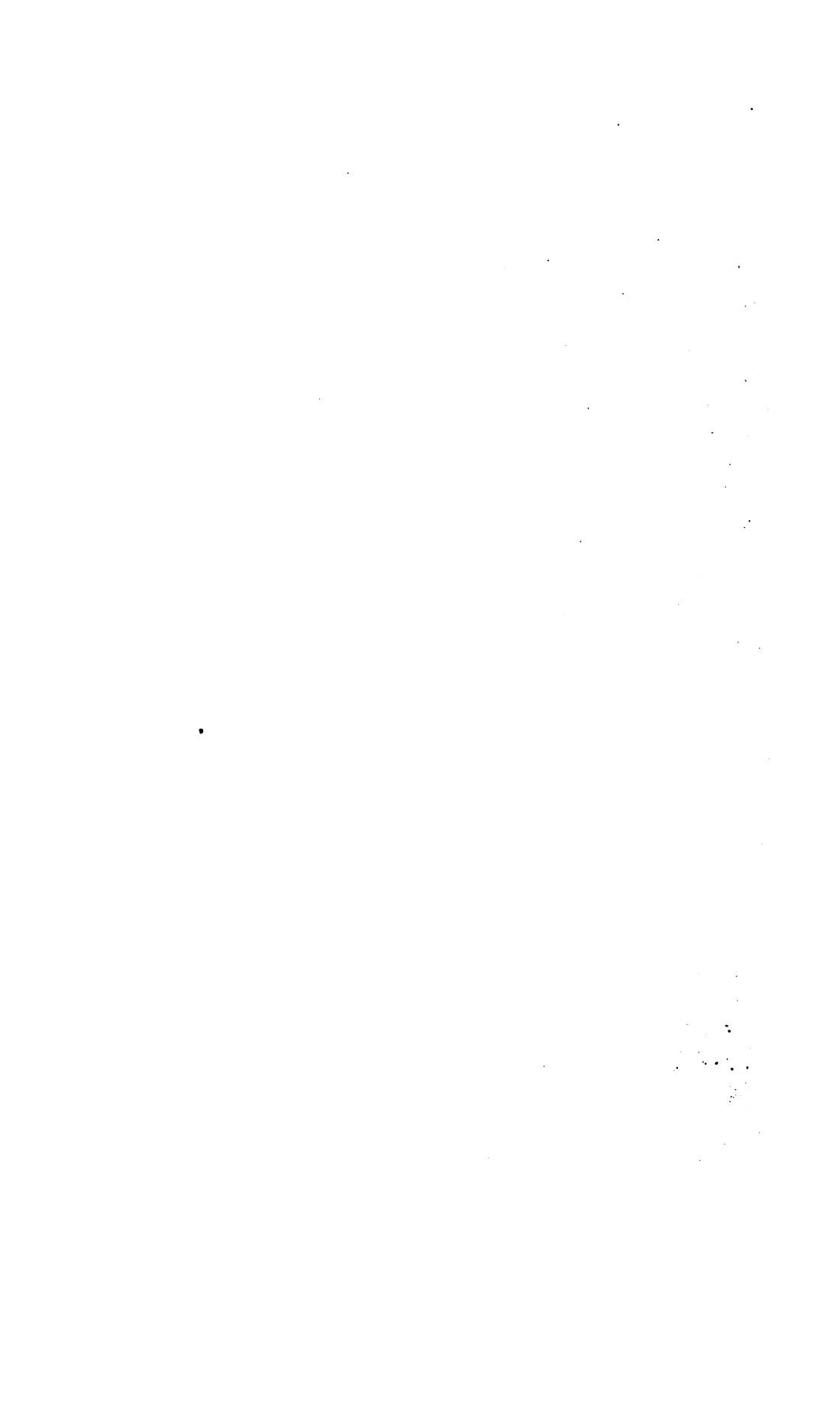
1. Crystals of uric acid, even when there is a deficiency of that constituent in the urine.

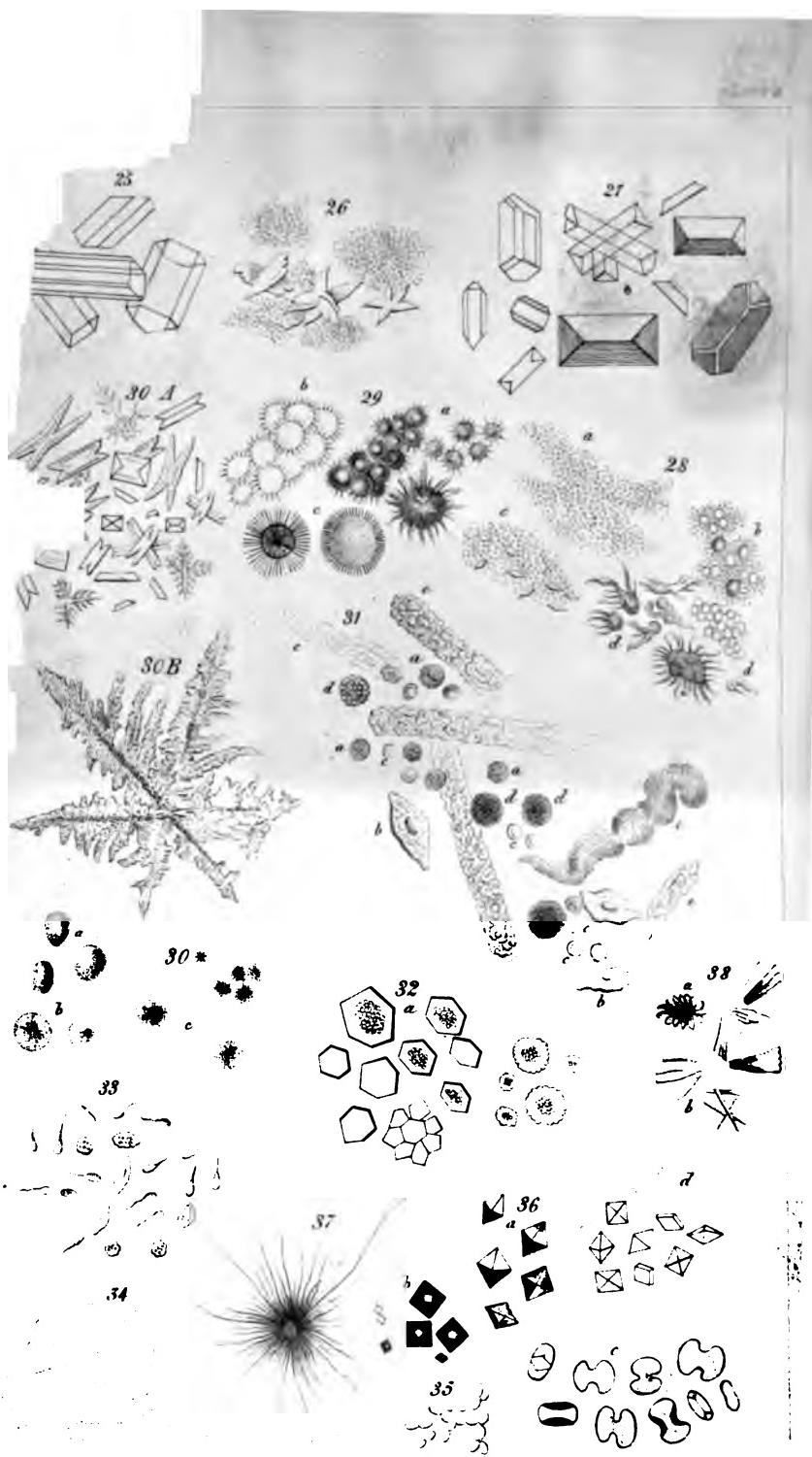
2. Urate of ammonia, generally in the early stages.

3. Pus-corpuscles, usually in the latter stages.

4. Blue crystals of uroglauclin, usually after the urine has stood for some time.

5. Ammoniaco-magnesian phosphate, when the urine contains carbonate of ammonia.





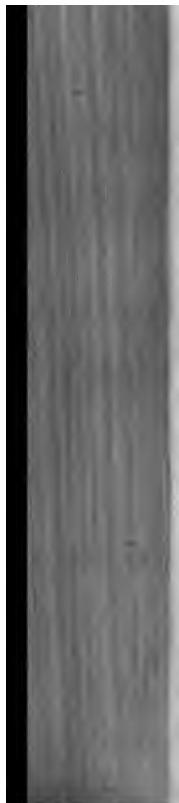
EXPLANATION OF PLATE II.

Fig. 13. Saliva.

- 13* *A.* Colostrum. *B.* Healthy milk.
- 14. Epithelium.
- 15. Nasal mucus.
- 16. Bronchial mucus, with the corpuscles seen in other forms of mucus.
- 17. Pus from the lungs.
- 18. Tuberclie.
- 19. Peculiar forms occurring in tubercle.
- 20. Pure urea from urine.
- 21. Nitrate of urea from urine.
- 22. Oxalate of urea from urine.
- 23. Various forms of uric-acid crystals.
- 23* Various forms of hippuric acid.
- 24. *A.* and *B.* Chloride of sodium as it crystallizes from urine.

EXPLANATION OF PLATE III.

- Fig. 25. Phosphate of ammonia and soda from evaporated urine.*
- 26. Phosphate of lime from a urinary sediment. [The foliaceous bodies are most probably urates.]
 - 27. Ammoniaco-magnesian phosphate from an urinary sediment.
 - 28. Various forms of urate of ammonia from urinary sediments.
 - 29. Various forms of urate of soda from urinary sediments.
 - 30. *A.* and *B.* Various forms in which an acid solution of the earthy phosphates is precipitated by ammonia.
 - 30* Carbonate of lime.
 - 31. The sediment occurring in Bright's disease.
 - 32. Cystin.
 - 33. Seminal animalcules and granules.
 - 34. Cholesterin.
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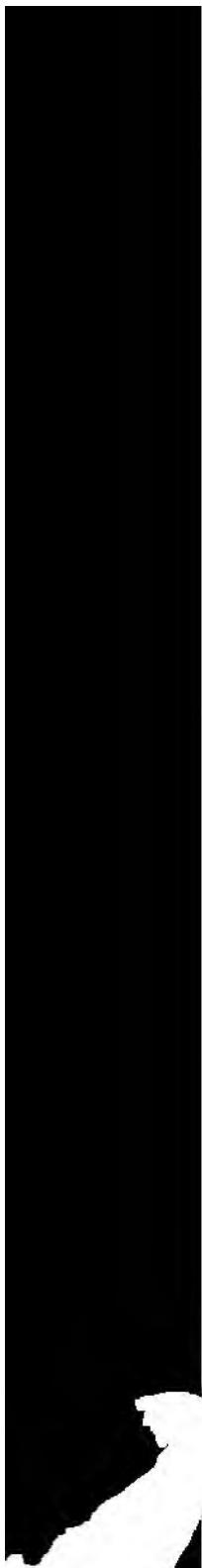
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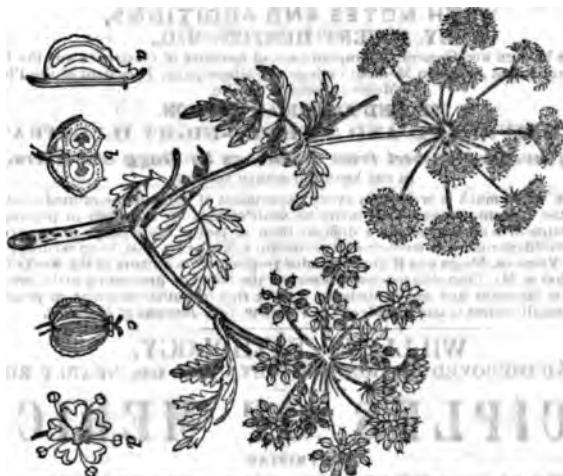


FIG. 72.

CONIUM MACULATUM.
(Hemlock.)

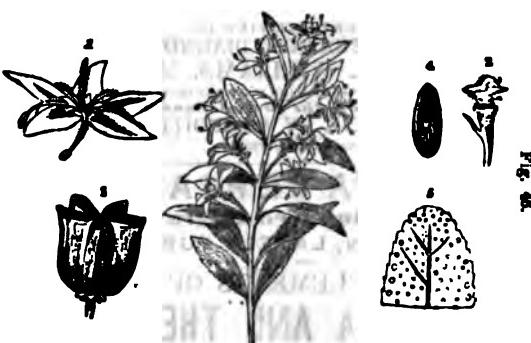


FIG. 64.

DIOSMA CRENATA.
(Rue.)

MYRISTICA OFFICINALIS.
(Nutmeg.)



FIG. 85.

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